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OUT OF THE TEST TUBE

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So firmly do I believe that there are thousands of intelligent, yet non-technical people who have some interest in chemistry, who would like to penetrate beyond its "wonders" to an appreciation of its methods; thousands who want to understand our research, our reasoning, in order that they may relate chemistry to daily life, to economics, to social relations, to the arts, to national defense, and to world affairs; that I have dared to write directly to the layman. (*Out of the Test Tube*, Long and Smith, New York)

While this intelligent layman yawns comfortably in his easy chair, chemistry wages desperate battles on many fronts—against disease bacteria that have from time to time threatened to exterminate the race of men; against the frowns and mysteries of Nature.

The weapons are drawn, not from scabbard, quiver or cartridge belt, but from the test tube. Some are used quietly by physician and surgeon in the fight with Death, others are violent in the hands of engineers.

There have been impressive victories in some salients like the glorious chemical conquest of the air by which limitless atmospheric nitrogen can be converted into fertilizers and explosives.

The struggle against rocks, reefs, and mountains is being won with chemical forces released from high explosives to make mining, road-building, tunneling, navigation, cheaper and safer. But the red rust is only half conquered and the chemist has

failed miserably to duplicate the skill of the green leaf in converting sunbeams into food and fuel.

For a time it seemed that the motor age would pass with the exhaustion of oil supplies, but that particular spectre has been driven, by the research chemist, into the shadows of a far distant future. In the meantime nations maneuver to gain control of oil fields and of those mineral deposits that mean world power. Each country strives to become self-sufficient. Germany broke the camphor monopoly of Japan by synthesis, from turpentine, of this essential ingredient of picture films and our own people have just learned how to make synthetic rubber of a sort.

"Believe it or not," any intelligent layman who joins us in keeping an eye on what comes Out Of The Test Tube will come to realize that he lives in a chemical world, and in a chemical age. Broad culture forces him to a better understanding of this civilization.

As H. E. Howe, famous editor of *Industrial and Engineering Chemistry*, once said, "We have had enough books on the wonders of chemistry and now we need a book for the public on how we chemists do things." That indicates the purpose of this book. There is a scientific system in the development of topics and the scientific viewpoint is presented yet the language is "popular." To capture interest many line drawings, some of them distinctly humorous, have been used.

A few quotations from the book may serve as evidence for the argument presented above.

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A Caesar enjoyed breakfast in your house this morning. Born to the purple, accustomed to levy upon remote regions of an empire for luxuries to gratify his fancies, wont to think of his royal presence as the center of a wide world, he started the day right with a liberal use of soap in the bath. No thought did he give to the chemical origin of soap or the involved chemistry of its cleansing function, yet when an alloy steel razor blade drew blood he was quick to seek antiseptic safety in the well-stocked medicine cabinet.

For the imperial breakfast, agricultural and horticultural minions a thousand miles distant had labored and a vast network of transportation lines converged. His morning paper collected in his hand the world news that raced along a thousand wires and his telephone waited for royal speech with any one of

millions. After breakfast Caesar stepped into a luxurious, rubber-tired chariot, cracked the master's whip over a hundred chemical horses, and was drawn swiftly to scenes of work or play.

At every step in this well-begun, modern day he utilized chemical materials, chemically improved, and chemical processes as simple as the explosion of gasoline or as complex as the digestion of the royal breakfast.

You are that Caesar and this chemical world is still yours to command.

Man has climbed a long way up from savagery, up from superstitious fears of natural forces, up from the delusion of coincidence, since he quit swinging from tree to tree by prehensile tail. Our primitive ancestors were slow to observe closely, slow to classify and compare observations, and slower still to base sound predictions of future behaviour of creatures or materials upon such observations.

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Under the chapter title of the "Importance of Nothing at All," is found this:

"If from a vessel holding a quart there were removed one million molecules a second, it would take 750,000,000 years to remove practically all of its air, but the Langmuir pump accomplishes this in just two seconds." Even so, our highest vacua are quite dense as compared to some of the distant stars, "incandescent masses of nothing at all."

High vacua, or even partial vacua, minister to our comfort and serve us well in many ways; they made possible the original incandescent lamp (although the type has since changed), the X-ray tube, the radio bulb, the photoelectric cell of television, the thermos bottle, suction pumps, and they increase the efficiency of steam engines and turbines.

The color effects accompanying electrical discharges in rarefied gases have made possible the cheap but ghostly light from mercury vapor lamps much used in factories, and the beautiful pink glow of the neon tubes used for advertising signs. Probably the magnificent effects of the aurora borealis are due to similar discharges through the highly attenuated atmosphere a hundred miles above us.

And so it appears that, by the vital aid of practically nothing at all, the vision of physicians and surgeons is so extended

that human suffering is alleviated through correct diagnosis; cancerous growths are in some measure controlled; curative summer sunshine is available in the darkest days of winter; the electric lighting of homes was made possible; the actual voice of speaker or orchestra is heard without any effort by countless millions; the "electrical eye," like an educated robot, controls factory operations; and hot food is kept hot and cold drinks cold, for lunch or picnic.

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Under "Chemical Warfare," the reader is told that on approach of bombing planes the city population should retreat to the upper floors, close all windows and doors, shut off ventilating devices—and wait for breezes to blow away the toxic gases, smokes and mists. With gases proper this means a very short wait, but mustard droplets persist, volatilizing slowly. However, a masked fire department could profitably hose down the streets and perhaps the roof areas (really the greater fraction of a city area) or the city could be gassed by its own citizens with chemicals which would clean up mustard by converting it into harmless compounds.

It may comfort uneasy New Yorkers to learn that although 20 milligrams of mustard gas placed exactly in the lungs may be fatal it actually took two tons during the war to secure a single death and twenty-nine casualties. Careful calculation indicates that 14,000 airplanes carrying a ton each of phosgene would be required to gas New York effectively.

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"High Explosive, the Liberator," is introduced by this paragraph:

A great Roman aqueduct built by the Emperor Claudius had to be carried through Monte Solviano by a tunnel, three and a half miles in length. What was that to the most powerful ruler in the world with innumerable slaves to do his bidding? Yet today a competent American engineer actually controls more power than the Roman despot ever had. Claudius had to wait eleven years for 30,000 slaves, toiling underground, to lead that tunnel five feet a day, while a modern engineer with a hundred men and tons of dynamite could do it comfortably in ten months. Those tons of dynamite liberated an army of toiling slaves.

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Just as hydrogenation of petroleum has been tried so has high-pressure, catalyzed hydrogenation of German lignite tar been thoroughly tested by Bergius and others. Since Germany lacks oil of her own for motor fuel it may be an economic advantage and a military necessity for her to prepare gasoline equivalents from her own coal or lignite. Bergius succeeded but just now his process can not compete with gasoline at the present low prices.

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Two thousand years ago royalty and the wealthiest nobility were "born to the purple" for only they could afford to pay $600 a pound for cotton cloth dyed with the precious secretion of *murex*, a tiny shellfish of the Eastern Mediterranean. The distinction associated with inherited wealth really belonged to the modest *murex* which had brains enough to secrete di-brom indigo.

Since shellfish are notoriously silent the secret of the composition of the purple dye was kept through the ages until Friedlander in 1909 analyzed this "Tyrian purple," which had once brought wealth to the merchants of ancient Tyre, and found it to be identical with a synthetic derivative of indigo prepared five years earlier and discarded as inferior. How are the mighty fallen! The most regal dye of those by-gone days of fabulous Oriental magnificence now rejected as not good enough for the pampered taste of shop girls!

It is the fashion now to sigh for the days of the "vegetable dyes" and to refer to modern "coal tar dyes" as glaring and fugitive. As a matter of fact these vegetable dyes were few in number and very unexciting in beauty—only logwood black and fustian yellow surviving the competition. Now, thanks to coal tar chemistry, a thousand dyes of every conceivable hue are offered for your capricious taste and, if you insist, four thousand more could be marketed. In the United States over $30,000,000 annually are spent in dye research in order that milady may be gowned more beautifully than the Queen of Sheba.

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It is astonishing to find how many nuts and seeds yield fatty oils on pressing or heating. Sunflower seed oil in Russia is produced in great quantities as a food. Almond oil, castor bean oil, peanut oil, corn oil, soy bean oil, coconut oil we all know, but

have you heard of chaulmoogra oil, expressed from the seeds of a rather rare tree in the East Indies? In this fat lies the best hope of a cure for leprosy, yet the medicine is almost too indigestible for endurance. Consequently chemists have split this fat, coupled its acids with other alcohols than glycerine and, in general, substituted things in the molecule in the hope that the good effects might be retained while the bad might be cast aside. A fair degree of success has rewarded such efforts, so this age-old curse of the Orient may finally yield to modern science.

Do you know that the bacteria of tuberculosis are richer in fat or wax than any other living thing—that they contain nearly 40 percent? Chemists at Yale have grown cultures of tubercle bacilli on a factory basis, separated this fat or wax, injected it into animals and produced some of the disorders associated with the disease. It is quite different from all other fats, a trouble maker.

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It may strain your credulity to hint that armies might use yeasts as weapons but we shall risk it. During the war Germany lacked enough fat to feed the nation, to make soap and to yield glycerine, the starting point in the manufacture of nitroglycerine. A yeast capable of fermenting common sugar into glycerine in great quantities was discovered and used, yielding 1,000 tons per month.

Possibly the average citizen believes he can do very well, thank you, without molds, associating them as he does with the green or blue or white whiskers often seen on spoiled bread, or fruit, or shoes discarded in moist weather. Yet it is to specially selected strains of molds that we owe the more or less delicate flavors of Camembert, Roquefort and similar cheeses.

The citric acid used in many "soft" drinks is now prepared in thousands of tons from cane sugar by the aid of a special mold. The lemon tree has found a rival. Quite recently Herrick and May have cultivated another mold able to convert glucose into gluconic acid. This rare acid once priced at $100 per pound may now be manufactured at a fraction of a dollar per pound but, as yet, the demand is trifling. Calcium gluconate, its salt, promises to become a better source of calcium in nutrition than other calcium compounds. In 1933 Ward and Lockwood of the United States Bureau of Chemistry found a mold, *Penicillium javanicum* that converts glucose into fat within twelve days.

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From the chapter headed "The Farm As A Factory" we quote this:

Out in California a desert ranch has been planted to the scrubby guayule, rich in rubber latex. After years of research they have learned how to manage it so the path is cleared for rubber farming on the desert, of which we have plenty. If Edison's research on production of rubber from goldenrod is continued successfully a new kind of farming, "weed farming" will be introduced. Why not?

McKee has developed a hybrid poplar that after ten years of growth may yield 3,000 to 4,000 pounds of pulpwood per acre per year. The United States paper pulp industry has been driven to Canada for lack of raw material. We should treat the forest as a crop and supply the pulpwood. Charles Herty, down in Georgia, is just now proving with a small factory, that good white paper can be made from young "slash pine"—another quickly-grown crop. Farm and forest go together. The South has 100,000,000 acres of unproductive, cut-over timber land that should be cropped with young pines, cut after ten years or less before increasing content of resin makes paper making too difficult.

Sawdust fails to appeal to the farmer as a crop and yet, as Bergius shows in Germany, it can be treated with concentrated hydrochloric acid to yield pure carbohydrates equal to 60 per cent of the weight of dry wood. The product has been proved to be excellent stock food. It is not predicted that this process will soon be worked in the United States but it gives us confidence in the basic importance of cellulose as a great crop, the greatest crop in the world.

REFRIGERATING UNIT RUN "IN REVERSE" USED TO HEAT BUILDING IN SALEM, N. J.

By running a refrigerating unit in "reverse," heating engineers of this city are now heating a building by taking the heat from the cold air outside.

The device really makes the air outside colder and the heat removed is delivered to the building. This is the same action taking place in an automatic refrigerator which is cooled by taking heat from it and dissipating it to the air outside the box.

Engineers of the General Electric Company and the American Gas and Electric Company who built and installed the device foresee that the mechanism can have the dual purpose of heating the building in winter and cooling it in summer by operating the mechanism either one way or the other.

ALGEBRA AS A MEDIUM FOR THE INTERPRETATION AND CONTROL OF NATURE

By Merton Taylor Goodrich
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Not only does it give delight to find algebraic laws in nature, but the discovery and application of these laws make the world a happier and better place in which to live. It is a joy to perceive that there is a relation between speed, time, and distance which can be represented by a simple formula. But it is an even greater pleasure to find that by means of algebraic formulas, machines can be constructed for the production and control of motion. Not only does algebra increase our happiness by unfolding before us a larger meaning to nature than could otherwise be found, but the study of algebra leads directly to the control of nature and the pleasures that come from the possession of these powers. In brief, algebra may be considered as a medium for the interpretation and control of nature.

The world in general does not use algebra to solve puzzle problems, to remove complicated nests of parentheses, or to perform other valueless tedious tasks. Society uses algebra to shape the wings of the airplane, to build the headlights of an automobile, to arrange the parts of a radio tube. Our present civilization could not exist without algebra. Society makes use of algebra to obtain new meanings to the universe and to control the forces which it discovers.

It is impossible to control the force of exploding gasoline without the use of formulas for the construction of cylinders and valves. It is impossible to control the force of electricity without formulas which determine how the wires shall be wound on the generator. At the present time, the natural and the social sciences are finding it desirable to use symbols and formulas to clarify their terminology and to establish their laws more definitely. To an increasing extent, all sciences are making use of simple algebra. Society is finding algebra useful not only in the study of numbers, forms, and forces, but in such studies of real life as are illustrated by the Mendelian law. When a law is determined with sufficient certainty to be represented by a formula, it becomes algebraic. But not until a law has become algebraic can it be used effectively or accurately for the control of nature.

Let us then refrain from teaching algebra as a tool subject for the solution of obsolete and absurd problems, such as, how long it will take a dog to catch a rabbit or how long it will take an automobile to overtake a bicycle. Let us not make algebra a monotonous series of tedious drills.

When algebra is regarded merely as a tool subject, when it is taught in a mechanistic way, many pupils hate it and there is justification for their attitude.

Let us teach algebra as a real, living, power-giving subject. Then, teaching algebra will become an enjoyable occupation, and studying it will be a thrilling, happy experience.

It is natural for human beings to use symbols even in childhood. The toy automobile is a symbol for a fire truck or a five passenger car. The doll is a symbol for a darling baby, a little boy, or a little girl. Some see a symbolism in all nature and, as an illustration, think of a flower as a symbol for a divine thought. For these reasons, algebraic symbols are not to be taught as meaningless characters to be juggled at will. Algebraic symbols are to be taught as the normal development of the natural instinct to symbolize. Leading pupils to see that the symbols of algebra may be used to represent elements and factors in real life just as toys are used, leading pupils to see that by the use of symbols formulas may be written which represent real relationships, leading pupils to see that the symbols and formulas of algebra show the order that pervades the universe, leading them to see how the laws of nature may be interpreted and controlled by the aid of algebra, is leading them ultimately to appreciate more fully the laws of God.

Specifically this means the teaching of all things concretely as far as possible, so that negative numbers actually can be observed as common in the daily life of the people, so that pupils in the class room can derive simple formulas experimentally or demonstrate dramatically the existence of complex numbers.

When pupils realize that algebra is a subject shining with beautiful symbols, that the formulas most commonly used are the simplest ones, and that algebra when taught concretely may be easily understood by the normal student, then pupils like to study it and teachers like to teach it. The study of algebra begins to give real pleasure just as soon as pupils see that it gives a broader and fuller meaning to life, and this pleasure increases as to this power of interpretation is added the power to control nature.

SIMPLE STAINING PROCEDURES THAT AROUSE INTEREST IN BACTERIA

By Russell W. Cumley
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The present staining methods employed in preparing bacteria slides for use in the secondary sciences are methods which are used by technically trained bacteriologists. The advantages of many such staining procedures are probably never realized by the majority of general science teachers, because the objectives of the bacteriologist and the high school general science teacher differ considerably. The research man is interested in morphological and physiological details such as the possible occurrence of nuclei and of chromatin granules, the chemical activity of bacteria, and so forth. The general science teacher is interested in arousing in the students a curiosity and interest regarding bacteria; and the notions of nuclei and capsules are as abstractions to the teacher and the pupils. It need not be argued that the teacher's point of view is of an importance equal to that of the scientist.

The development of staining, however, has been left entirely in the hands of the research man. Consequently, his staining technics have been employed altogether in preparing slides for study in the secondary schools. University students, while taking courses in bacteriology, adopt the attitudes and technics of their professors; and upon going out into the teaching field, they seldom change the methods of demonstration to meet the demands of their vocation. As a result, bacteriology has not attained a prominence in secondary education that would be anticipated from a consideration of its importance to life and industry. The biological houses sell stained preparations which, when placed under a 4 mm. objective, are quite often difficult or impossible to find. Even if the stains are good Gram stains, the student will be only mildly interested in seeing a few dark cocci or pink bacilli. Nor will he be particularly stirred upon being told that the tiny object before him is the sole cause of the death of grandma, or of the souring of milk. Furthermore, practically all that the supply houses sell are pure culture studies, either of the pathogenic bacteria or of some of the more common non-pathogenic forms. Nearly all of the films are positively stained and are difficult to locate on the slide. A large part of them are stained to bring out some morphological detail which

is of but little interest to the general science teacher. Finally, pure culture slides sold by commercial houses are often considered beyond the means of a science department.

Regardless of this state of affairs, as a result of which interest in the field of bacteriology has been negligible, hardly any active steps have been taken by the science teachers, the scientists, or the supply houses, in finding a remedy. And so, after observing several hundred times the infinitely mild response on the part of the students when presented with Gram or methylene blue stains, the author felt the need of a crusade in bacteriological staining procedures for secondary sciences.

Considerable experimenting revealed that interest, active emotional interest, could be aroused by instituting two methods in bacteriological staining:

1. Preparations of mixed cultures, appropriately labelled, "Forms from Air," "Forms from Hydrant Water," "Forms from Soil," "Forms from a Boil," "Forms from Milk," "Forms from a Pencil," etc.

2. Use of attractive negative stains in preference to the usual and ordinary positive stains. In these negative preparations the bacteria are unstained and stand out brilliantly against a deep blue or black background created by the dye.

The first procedure assures active interest on the part of the child, for he can actually see what he gets in his mouth when he gnaws the end of his pencil. And of course, children are not so much concerned with the capsulation of the pneumococcus as they are with keeping their own persons free and secure from the invasion of strange races. The second innovation, that of the negative staining method, assures visibility of the organisms. Ordinarily, an oil immersion lens is unnecessary. A 4 mm. objective provides sufficient magnification for most of the more common bacteria.

It is not particularly difficult to obtain material for the preparation of these slides. The organisms may be grown in mixed cultures in broth, care being taken not to let the culture get old and cause either death, sporulation, or inhibition of any particularly desirable organism; or a number of organisms from the particular habitat may be grown in pure culture and then mixed In either case the organisms may be concentrated by centrifuging and then pipetting off the supernatant liquid.

Regarding the negative stains, there are five simple methods, any of which is good. They are as follows:

1. *Burri's India Ink Method.* This is the simplest to prepare and gives fine results. Any good grade of India Ink may be used. Dilute 1:1 with water and sterilize. It is recommended that the mixture be allowed to settle two weeks and then only the upper part of the suspension used.[1] However, good results have been obtained by using the ink immediately after mixing. A small portion of the colony of the bacteria or a loopful of broth in which the bacteria have been concentrated is mixed on the slide in one drop of the ink. The film is spread over practically the whole surface of the slide, and the slide is then tilted at an almost vertical angle so that the excess ink will drain off and not cause the film to crack up through a concentration of the ink in any one place on the slide. When dry, it is ready to be examined or covered with a cover slip. The background is black or gray, granular, with the bacteria unstained. Pupils can easily learn to make this sort of stain, and they generally take to it rather pleasurably.

2. *Fischer's Nigrosin Method.* This is a simple method with excellent results. Fischer's technic is as follows:[2]

> Boil 10 grams Nigrosin in 100 cc. water about 30 minutes. Filter several times through the same filter paper, adding 10 drops of formalin before the last filtration as a preservative. Place a small loopful of this solution on a clean slide and add the bacteria with a needle or loop. After mixing spread the mixture a little irregularly on the slide and dry either at room temperature or slowly over a low flame.

The author recommends a 5% in preference to a 10% solution, even when broth cultures are used. Better results have been obtained by using a large drop of the 5% solution spread over the entire area of the slide, provided that the slide is then tilted at an angle of from 30° to 60° with the horizontal, so that the excess stain will drain off, and the film dried in air. The bacteria stand out beautifully against a blue-black field. This is probably the prettiest of all negative preparations, and with a little practice the pupils can learn the technic.

Aside from the beauty of the preparation, however, this method has some distinct advantages over the other technics. It is extremely simple; it is rapid, both in preparing and in drying; it is homogeneous and does not present the finely granular appearance of the India Ink; and, if a differential stain is required, it is possible to use nigrosin in distinguishing Gram-

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[1] Lehmann-Neumann-Breed, *Determinative Bacteriology*, Vol. I, p. 5, 1931.
[2] Dorner, W. Ch. "The Negative Staining of Bacteria," *Stain Technology*, Vol. V, p. 25, 1930.

positive from Gram-negative organisms. In regard to this differential quality, Dorner remarks:[3]

> Another advantage of the nigrosin technic is that many bacteria of the Gram-negative group have a characteristic appearance when thus stained. Many Gram-negative rods show a little dark dot in their center. If this dot is visible one can be sure that the organism is Gram-negative (altho these spots are not always present in an organism of this group) for it has never been observed in the Gram-positive organisms.

3. *Benian's Congo Red Method.* This stain makes an attractive slide. Its outstanding disadvantages are: (1), it requires the use of ethyl alcohol; (2), it is difficult to make a film without cracks; (3), the blue acid form of the salt (Congo red is a sodium salt of the azobenzene group of dyes) is likely to fade to the alkaline state, red, in which the powder is prepared and sold. Lewis recommends the following technic:[4]

> (1) Place a drop of 2% aqueous Congo red solution on a clean slide.
> (2) Mix with a loopful of the culture or equivalent amount of original material and let dry for about 10 minutes.
> (3) Cover the film with alcohol containing 1.0 or 2.0% HCl. The film becomes blue. Dry without washing. Dead cells are stained slightly, while living cells contrast sharply with the blue background. Bacteria from the teeth make beautiful preparations.

Instead of (2) above, it has been found, as in the previous stains, that when the stain and the bacteria are mixed, if the slide is tilted at a high angle, the occurrence of cracks will be minimized. Also, the one drop of stain with the bacteria in it should be spread over the whole length of the slide. Even with this caution, however, cracks often appear, apparently for no reason at all. This method is probably too uncertain and difficult for the pupil, although the teacher should find it quite easy to make good slides if sufficient attention be paid to the problem of cracking.

4. *Eisenberg's "Cyanochin" Method.* Eisenberg's original report is quite indefinite as to details. Experimentation has revealed that the following method is applicable: Prepare an aqueous solution in which there is 10% Aniline blue and 0.75% Cyanosine. Heat to get all the dye in solution. Filter several times. Apply as in the case of the Nigrosin method.

The difficulties of this method are: (1), the film often cracks badly; (2), the Aniline blue is inconstant and irregular in its results; (3), Gram-positive organisms are stained a faint pink by the cyanosine instead of remaining colorless and, conse-

[3] *Ibid.*, p. 27.
[4] Lewis, I. M., *A Laboratory Manual of General Bacteriology*, p. 100, 1929.

quently, they are not as visible as they would be provided they were not stained. This last objection is not only vitiated but becomes a positive asset if differential qualities are required in the stain.

This stain presents a fine azure-blue background against which the bacteria stand out conspicuously as unstained or faintly stained objects. The chief objection is the cracking. It is probably too complicated and uncertain for children to perform.

5. *Aniline Blue Method.* Fair results have been obtained with a 10% aqueous solution of Aniline Blue, heated to dissolve all the stain, and filtered. The method of application is the same as in the "Cyanochin" method. Organisms are totally unstained with the same azure-blue background as may be observed in the Eisenberg mixture. The advantages over the preceding are: (1), no difficulty in mixing; (2), only one stain is necessary; (3), no organisms are stained. The chief disadvantages are: (1), the stain cracks up badly on the slide, this preparation and the "Cyanochin" preparation giving the most trouble of all in this regard; (2), the fickle quality of the Aniline blue.

In summing up the advantages of these negative staining technics it may be said that: (1), stains by these methods do not require an oil immersion objective for many of the more common bacteria; (2), water is the solvent in all five stains; (3), alcohol is necessary in the Congo red method alone, and it has been suggested that it may be possible to substitute a good grade of rubbing alcohol treated with 1.0 to 2.0% HCl for the ethyl alcohol, which is almost impossible to get without a great deal of red tape; (4), the technics are simple and easily mastered by the untrained science teacher; (5), the negative stain, since it requires no previous heat or mordant treatment, probably presents the bacteria in their most natural state with a minimum of distortion; (6), these stains are good stimulants for the child's curiosity and imagination, and active awakening of interest often results from their presentation.

Dyes are sold by most of the larger chemical and biological supply houses. In ordering specify the following:

Nigrosine, Water Soluble, Schultz No. 700, C. I. No. 865.
Congo Red, Schultz No. 307, C. I. No. 370.
Aniline Blue, (Syn. *China Blue*), Schultz No. 539, C. I. No. 707.
Cyanosine, (Syn. *Phloxine B* or *Eosin* 10 *B*), Schultz No. 596, C. I. No. 778.

The cost varies from one to two dollars for ten grams for any of these stains.

An energetic science teacher, with an expenditure of eight or ten dollars for supplies and a few days of hard work, can make up an adequate set of such slides for demonstration. However, if sufficient time and equipment for making media, sterilizing, incubating, and centrifuging are not available, then small sets of prepared slides, wherein the foregoing ideas have been adopted, may be purchased from one of the larger supply houses at a moderate price.[5]

[5] The Central Scientific Company, Chicago, Ill.

FIGHT AGAINST SMALLPOX NOT YET ENTIRELY WON

New York, Nov.—The fight against smallpox has not yet been entirely won. Statisticians of the Metropolitan Life Insurance Company make this statement in spite of the fact that their figures show there was less of this dread disease in the United States and Canada in 1933 than ever before and that the records for the first seven months of 1934 promise a further drop in the number of smallpox cases. Significant is the fact that fully three-fourths of the smallpox cases reported by American states in 1933 occurred in only 12 states whose population is only one-fifth of that of the entire country.

"Generally speaking, these states are the ones in which popular sentiment has been most opposed to compulsory vaccination," the statisticians point out.

The twelve states are California, Colorado, Idaho, Iowa, Montana, Nevada, Oklahoma, Oregon, Texas, Utah, Washington, and Wisconsin. Falling in the same class of above-average prevalence of smallpox during 1933 was the Canadian province of Saskatchewan.

From "L'Ensignement Scientifique" of Oct. 25, 1934. Review of an article by L. Cook in SCHOOL SCIENCE AND MATHEMATICS of October, 1933. Translated by J. Colin Moore.

"This very simple method gives the immediate determination of the frequency of an alternating current. Here is the principle: a neon lamp, illuminated by an alternating current, is mounted on the periphery of a rotating, circular disk. As a result of the persistence of vision, there appears a certain number of positions of the lamp for a definite velocity of rotation. For instance, if the frequency of the current is 60 and if the disk rotates at the rate of 20 times a minute, 6 positions of the lamp appear."

This simple and interesting experiment may be used as a part of the course or as a demonstration.

The apparatus used by the author is rather complicated. As a variation of this experiment, we suggest a shiny nail head in a black disk which is illuminated by a stationary neon lamp. The results will be the same.

M. GINAT

SCIENCE—A METHOD OF OBTAINING TESTED KNOWLEDGE

By Ernest E. Bayles
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[Dr. Bayles is presenting two series of radio broadcasts during the present school year over the Kansas University station, KFKU, operating on a wave length of 1220 kilocycles. The first seres is entitled "Studies of Living Things." The time is 2:30 P.M., C.S.T., each and every Wednesday. This series is addressed particularly to high school biology and general science classes, a growing number of which are listening in regularly. In this series the subject matter is organized on the basis of a considerably modified Morrison unit plan and the attempt is made to make the broadcasts illustrative of the best of classroom teaching, in so far as this is possible in radio broadcasts. The present article is the fourth broadcast of this series.

The second series is entitled "The Art of Teaching." The broadcasts occur on alternate Wednesday evenings at 6:15 P.M. This series is addressed particularly to high school teachers. It deals with the general problems of teaching theory. The unusual feature of these broadcasts is that the two series, being presented by the same person, are made to dovetail very closely one with the other, thereby giving a very practical turn to the evening series of talks, and at the same time giving to the afternoon series a far wider significance than it would otherwise possess. In the evening talks certain features particularly represented by the afternoon broadcasts serve as the point of departure for theoretical discussions which thus possess a degree of tangibility and practicality which is unusual.—*Editor*]

Before proceeding very far into the study of a given subject, it is usually considered by teachers to be good practice to make at least a brief study of the general nature of the subject and of its place in relation to other subjects.

Biology is considered by most people to be one of the natural sciences. It may be well for us to pause for today, before we take up the general question of how living things are adapted to their environment, to consider *whether* the fact that biology is classed as one of the natural sciences should be recognized as we study it.

What kind of plan must we follow—or must we follow any particular plan—when we make a study of a subject classed as one of the natural sciences? We study living things in order to become better acquainted with them; to come to know more about them. But just what does this "coming to know more about them" mean?

One answer to this question might be that the study of living things requires the getting of more information about them—making a lot of observations and reading books, with the end in

view of remembering a lot of new facts. You have probably studied a number of school subjects in this manner, and are very well acquainted with that type of procedure. Let us see how desirable it is as a plan for study.

Have you found it desirable to be able, at times, to remember or recall a number of facts learned in connection with some school subject which you have studied? Such an ability has, without doubt, proven helpful at examination time. I expect, however, that most of you have found many other opportunities for using the information learned in classrooms, and have been very happy to have taken the course, or courses, which enable you to store away such information and to have it "on tap" at the opportune time. To have at one's tongue's end a considerable number of facts, covering a rather wide range of currently discussed topics, is thought by most people to be a very desirable accomplishment. While very few of us care to take the time to memorize enough facts to become regular "walking encyclopedia," most of us, nevertheless, find it highly convenient to have a well-stocked memory; one which is capable of reproducing the right information at the right time. It would surely seem that any study of a new subject in the schoolroom should result in an enlargement of the stock of information which one carries around with him and is able to reproduce when wanted.

The question would therefore seem to turn to whether or not there is anything else that should be sought in the study of living things, and of just how important is the process of stocking the memory, when compared with such other outcomes as we may discover.

In trying to remember a particular group of facts, you have probably found that it is quite helpful to arrange these facts, by one method or another, into some form which enables you to recall the whole set merely by remembering one statement which furnishes the key to the group. In order to recall the different colors of the rainbow in their proper order, some people find it convenient to remember the name "Roy G. Biv." This name gives the initial letter of each of the various colors as it comes; red, orange, yellow, green, blue, indigo, violet. By remembering one name, the person is able to recall, in proper order, a list of seven names. Quite a saving!

Knowledge handled in this way, whether for the purpose of remembering it or for some other purpose, is said to be *organized*. It would look as if the *organization* of our knowledge would

be a rather desirable feature of our study of living things, for such a plan would enable us to do a much better job of remembering the various facts which we already know, together with those which we shall discover in the future.

The organization of knowledge, however, enables us to do much more than merely remember facts in an economical and effective way. Scientists are forever organizing the various facts which they are continually discovering. But their organization of these facts if for a purpose that is quite different from that of merely remembering the facts.

Scientists do not spend a great deal of effort or time trying to remember all the facts which have been discovered. They remember many of them, it is true, but if it happens that they have occasion to use certain facts which they do not remember, they go to a reference book and look them up.

The scientist's purpose in organizing his facts is probably quite different from any which you may happen to imagine offhand. The organization is not for the purpose of aiding in remembering; nor is it for the purpose of ready reference, as with a dictionary or a set of encyclopedia. The scientist's organization is for the purpose of looking forward, rather than backward. He is not interested in facts for their own sake; he is interested in using facts in such a manner as *to enable him to discover new facts*. His organization is for the purpose of promoting discovery. The scientist is continually on the hunt for new things, and his every effort is focused in that direction. The peculiar thing about him is that just as soon as he has discovered a new fact, just that quickly does he lose interest in that particular fact and go out on the hunt for other new facts. You are probably wondering, however, just how facts can be organized so as to lead to the discovery of new facts.

Robert Koch, a little German country doctor who lived from 1843 to 1910, furnishes us an excellent example. Sheep and cattle were dying of anthrax; Koch wondered why. What could be the cause of a malady which would seize a perfectly healthy sheep or cow, turning the hapless animal into a dead carcass overnight? He began peering into the bodies of dead animals, looking for something out of the ordinary; using a microscope given him by his wife. Suddenly he discovered something very unusual; tiny, rod-like specks present in the blackened blood of the animals dead of anthrax which were not present in the blood of healthy animals, either dead or alive. Were these mi-

nute specks the real cause of so horrible a disease? Two Frenchmen, Davaine and Rayer, had previously claimed, but not proven, that they were.

Koch must study these specks more closely; he must find a way to separate them from any and all other materials and then see whether they would then transmit the deadly anthrax. Before long he had it! He took the crystal-clear liquid from the eye of a beef, hung a single drop of it from the under side of a thin piece of glass, touched to the drop the slightest bit of spleen of a mouse just dead from anthrax, and placed the thin piece of glass, together with the inoculated hanging drop, upon a thick piece of glass out of which a concave well had been drilled. Thus he had imprisoned a very few of the suspected rod-like specks, at the same time keeping out all others, and could peer at them through his microscope as much as he liked.

What did he see? At first there were only a few; but very soon each prisoner began to grow, under Koch's very eyes, until soon the hanging drop was filled with thread-like tangles of these tiny specks joined end to end. They were alive! He transferred, with the utmost care, the smallest bit from the first hanging drop to a second one and looked again. Again the miracle took place, single germs growing into long threads of germs.

He repeated the process of inoculating new hanging drops until he had grown eight new generations. No bit of the original diseased spleen, from which he had obtained the grandparents of these eight generations of children and grandchildren, remained in the last drop. There was nothing in the little glass prison but the harmless eye-fluid from a beef and those fast-growing organisms.

Now, Koch wondered, would a portion of this final hanging drop with its microbes, cause mice to die of anthrax, just as bits of matter from the insides of cattle, sheep, and mice, dead from anthrax, would do? He tried it; deftly dipping the end of a tiny splinter of wood into the hanging drop and then pushing it under the skin at the base of the tail of a healthy mouse. The next day the unfortunate mouse was dead! The microbes had done it!

Koch tested and retested, to be sure that he had made no mistake, but the result was always the same. If you wish to read this story, gorgeously told, take home a copy of Paul DeKruif's "Microbe Hunters" and read the fourth chapter called "The Death Fighter." Much of the story we have had to leave untold.

For the present we would ask how this chain of instances illustrates the method of science.

Does this appear to be a case of rather aimless looking about; not seeking for anything in particular; just searching, with the hope that some valuable item of truth will be found lying in wait? It doesn't look that way. Koch's efforts were directed very definitely along the line of a previously adopted plan.

We do find, however, discoveries of great value to science and mankind which have come as the result of the rather aimless gropings of curious men. Among the great biologists, Antony van Leeuwenhoek (1632–1723), a Dutch janitor who for some unknown reason developed a mania for grinding the finest of lenses (magnifying glasses), and then looking through these lenses at everything he could think of examining. Leeuwenhoek has been called the "first of the microbe hunters" for it was he who, in the course of his peering through his many microscopes, discovered for the first time the presence of these tremendously small living things which we call germs. Leeuwenhoek was merely out to see what he could see. How could he have guessed ahead of time just what he was to find! It had never occurred to *any*, even the greatest scholars, to suspect that any living thing could be smaller than the naked eye could see.

The history of science is sprinkled rather profusely with discoveries made when the discoverer was looking for nothing in particular. In other cases, chance discoveries, of one sort or another, were made when the discoverer was, in fact, looking for something else entirely.

But neither of these chance methods was the method of Koch. That little German physician knew what he was after. Koch started with a problem. The problem before him, he cast about, at first somewhat blindly, looking for clues and gathering evidence wherever he could. But suddenly he got an idea—we call it an hypothesis. The microbes might have done it! Then to experiment with the utmost care, in order to find beyond the shadow of doubt, whether the microbes did it or not. And find it out he did! When, in the year 1876, Koch finished his job and made his report to the leading men of the German medical profession, these men were swept off their feet. There was nothing more to be said!

And here we have Koch's method: (1) a problem, (2) a search for possible solutions, (3) a guess as to which is the right solution (an hypothesis), and (4) the most thorough testing of the

consequences of that guess, of the way the hypothesis works in actual cases; a search to find whether or not it is the right solution—right in the sense of being the solution which effectively solves the problem.

Koch's method was considerably different from that of Leeuwenhoek, for while Leeuwenhoek was, in the main, merely searching to find what was to be found, without any special notion as to what those finds might be, Koch was continually trying to tell ahead of time what he *ought* to find, and was then directing his searching in such a manner as to test out his predictions. While the method of Leeuwenhoek has often been fruitful of very important scientific discoveries, especially when science was young and there was much which was likely to be discovered by mere chance, nevertheless, the method of Koch is the real method of science. Koch's method is the one which has been most fruitful of discoveries in the past, and will continue to be more and more fruitful as time goes on since the more easily discovered notions are the ones which are uncovered first and those less easily discovered are the ones which tend to hold over for the later searchers.

Thus we have the method of science—a method of obtaining tested knowledge; a method of careful scrutiny of known facts; of careful experimentation with the possibilities represented by a given hypothesis; of arriving at conclusions on the basis of evidence carefully and painstakingly collected. A method which demands that we arrive at beliefs only after exercising the most careful thought and accounting for all pertinent evidence.

FEATHERED CARUSOS' VOICES TO BE RECORDED BEFORE THEY DIE

Just as we can still hear the recorded voice of Caruso and other singers who are no longer living, we shall be able to hear the notes of bird species that are on the road to extinction. To secure sound as well as picture records of rare and disappearing birds, a Cornell University group of naturalists will take an elaborately equipped sound-and-camera truck into the wilds of the South and West next spring.

Not all the records are expected to be sweetly melodious. One bird the expedition especially wants to "catch," because it is so nearly extinct already, is the ivory-billed woodpecker. Its record will probably sound much like a riveting machine, interrupted by a hoarse shout or two, for woodpeckers' voices are not sweet. Another sought-for voice that could hardly be classified as a song is that of the whooping crane, now one of the rarest of American birds.

RELATIVE EFFICIENCY OF TWO METHODS OF APPROXIMATING THE ROOTS OF AN ALGEBRAIC EQUATION

By Cecil B. Read
The Municipal University of Wichita, Kansas

When presenting a method by which approximate values of the irrational roots of a numerical equation of degree higher than two may be computed, the usual custom is to teach students to solve by Horner's method. The method often seems to create the feeling, both in the student and in the teacher, that the entire process is extremely laborious. Recently textbooks have appeared which offer an alternative graphical method. The writer has been unable to find any comparison of the relative merits of the two methods. My personal opinion, corroborated by conversation with others who have had occasion to use results in later work, has been that it is of importance that a student be able to obtain a solution mathematically free from error. The method is not important, a correct answer is essential. If a method is available by which a student may obtain results equally as good with less time expended, either in learning or in using the method, it would seem to be the duty of teachers to consider the possibility of presenting this method rather than the traditional Horner's method.

In considering the preparation of a measuring instrument, one thing seemed preeminent. Although the complete solution of a problem is lengthy, the essential thing is that the student be able to obtain a correct answer. If the purpose were to diagnose difficulties, a test should no doubt consist of short elements of the process. However, the engineer, or the student, desiring to use a result in some other work, is not interested in a solution correct except for a few parts. A solution completely free from error is the thing of importance; there is no value in finding how few errors can be made, or how fast errors can be made.

It seemed advisable to use a test consisting of a single problem, requiring a solution free from error. The test used could be given to students using either method, the score being the number of minutes consumed in arriving at a correct solution. An error is penalized by the fact that the student must discover it and correct his work, resulting in a larger score. The test used was as follows:

Obtain, by Horner's method, *all* roots of the equation $x^3+4x^2-7=0$ Results are to be correct to three decimal places. Check your work by the fact that the sum of the roots is -4. Work as rapidly as you can without making errors.

A second form was identical except for the equation and the sum of the roots. For testing results obtained by teaching the graphical method, the same tests were used, substituting the word "graphically" for the words "by Horner's method." These tests have been used by the writer over a period of several years, at three different institutions. With 131 cases the Pearson product-moment coefficient of correlation is 0.891 ± 0.0124, which shows that the test used has sufficient reliability for the purpose intended.[1]

Two experiments were conducted in classes in regular freshman courses at the Municipal University of Wichita. At no time were students advised that an experiment was in progress. For one study, two sections of freshman algebra were used, one consisting of students who had presented one unit of high school algebra for entrance, the other consisting of students who had presented one and one-half units of high school algebra. These were regularly formed sections which might be considered to contain a random sample of freshman mathematics students.

The first section, consisting of twenty-four students, met five times weekly, the second, consisting of thirty students, three times weekly. To both sections the standard course was presented until the subject in question was reached, at which time the first section was presented with the details of Horner's method as given in the class text. After four class periods devoted to the subject the first form of the test was given. Next, the graphic method of solution, as presented in the same text, was presented. Three days were devoted to the study of this method, followed by the second form of the test, requiring graphic solution. With the second section the procedure was reversed, the graphic method being presented first. Again it was found necessary to devote three days to the graphic method, but four to Horner's method. In both sections problems were worked in detail in the class; students worked several problems as outside assignments; and there was no attempt to give the test until it was felt that the class had a grasp of the subject comparable to that usually desired before giving a test over any subject matter. Both sections had the same teacher (the writer),

[1] McCall, William A. "How to Experiment in Education." (New York, The Macmillan Company) p.112

who endeavored to be as impartial as humanly possible in presenting the methods.

Difficulties due to the schedule made it impracticable to form two equivalent groups as sections in algebra. There was also the probability that if two such sections could be formed at the start of the year, withdrawals during the period before the subject is reached would destroy the equivalence of the groups. It was decided, therefore, to select two groups of twenty students each from two sections of freshman algebra. Those selected were students who had offered one and one-half units of algebra for entrance. After a consideration of possible criteria for forming equivalent groups, it was decided to make use of: (1) the raw score on the National Council of Education psychological examination, (2) the average mark in all high school mathematics work, (3) the college mark for twelve weeks of freshman algebra. A majority of the students come from the Wichita high schools, insuring a fair amount of uniformity in high school marks. It seemed advisable to give each of these criteria equal weight, the desired result being obtained by weighting in such a manner as to leave the standard deviations of the new scores approximately equal. From the students available, twenty pairs were selected, leaving in each section some students who were not considered in the study. The mean composite scores for the two groups were 1373.675 and 1373.600, with S.D's of 106.48 and 103.34.

To one of these sections the graphical method of solution was presented, to the other, Horner's method. It was found necessary to devote three days to the graphical method, but four to Horner's method. No attempt was made to present the alternative method of solution to these sections. After the presentation of the subject matter, the first form of the test was given, followed by the second form at an interval of two days. The sum of the scores on the two tests was used in this case as a single score.

Since little information can be obtained directly from raw scores, tables have been prepared, summarizing the results.

Consideration of the tables indicates very definitely[2] that students will in general be able to obtain desired accuracy with less expenditure of time if they employ the graphic method instead of Horner's. In an effort to obtain additional confirma-

[2] *Ibid.*, p. 154–155.

tion, two groups of students used in determining the reliability of the test were again considered. The students were in different sections, under different teachers, there being no attempt to secure equivalent groups. Many of the control features of the other two studies were lacking. A much greater difference between mean times was obtained, again tending to confirm previous conclusions.

TABLE I

RESULTS OF COMPUTATIONS FOR THE ROTATION GROUP STUDY

	1	2	3	4
	Section I	*Section II*	*Section I*	*Section II*
	Horner's	*Graphic*	*Graphic*	*Horner's*
Mean	105.75	91.1	92.25	96.0
Standard deviation	15.681	18.517	18.036	18.574
S. D. of the mean	3.201	3.381	3.682	3.391
$\text{Mean}_1 + \text{Mean}_4$			201.75	
$\text{Mean}_2 + \text{Mean}_3$			183.1	
Difference			18.65	
S. D. of difference			6.836	
Experimental coefficient			0.981	

TABLE II

RESULTS OF COMPUTATIONS FOR THE EQUIVALENT GROUPS STUDY

	Graphical Method	*Horner's method*
Mean	177	200
Standard deviation	266.666	21.907
S. D. of the mean	5.963	4.905
Difference between means	23	
S. D. of difference	7.716	
Experimental coefficient	1.072	

It is not claimed that this study is conclusive, but it does indicate very definitely the need for consideration of the possibility of a change. Additional experiments with larger numbers would be needed. No claim is made that the graphic method gives the theory of Horner's method, in fact, some topics necessary for the presentation of Horner's method may be omitted if attention is restricted to the graphic method. Perhaps in an elementary course we might restrict our work to the obtaining of a solution, leaving for a more advanced course more difficult or alternative methods.

Accepting the more or less prevalent opinion that a correct answer is essential, the particular method used being immaterial, the results indicate that a solution by successive graphs enables the student to obtain desired results with less expenditure of time than Horner's method. Moreover, it would

seem that less time is required for the presentation of the subject matter to the students. With these advantages, teachers might well consider the possibility of a change in the methods used in handling this particular part of algebra.

ECONOMY IN THE CHEMICAL LABORATORY

By Chas. H. Stone
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In schools where ample funds are provided for the equipment and maintenance of the laboratories, the teacher need exercise no unusual care in trying to keep down expense; such attempts are sometimes classed as "picayune." But in many schools the funds provided for laboratory maintenance are limited or inadequate; in such schools the teacher may find it necessary to resort to all sorts of ingenious methods to make the available money go as far as possible. The following suggestions may prove of some service in this regard.

Bunsen burners. Where gas is available, burners should be provided, but it is quite unnecessary to provide each pupil with one. Even in schools where there may be several classes in chemistry, twenty burners will be found enough for many times twenty pupils. These burners, attached to the gas cocks by two and one-half feet of quarter inch rubber tubing, may remain on the desks all the time so that when one class passes out of the laboratory another may enter and use the same burners. In the better class of burners, an occasional overhauling to see that the movable parts do not become immovable through corrosion may be given now and then, and a little kerosene or machine oil applied to the screw threads will keep the burners serviceable for a long time.

Combustion cups, or deflagrating spoons. Pieces of hard chalk, or the ends of electric light carbons, attached to a wire handle can be used in place of the metal spoons furnished by dealers.

Files. All iron ware corrodes rapidly in the laboratory. For this reason as little iron ware as possible should be provided. Files of the triangular form are generally used only during the first few exercises when the class is practicing glass cutting and working. When this exercise is finished, all files may be collected, wrapped in oiled paper, and put away for use the following year. One or two files may be left out for the occasional use which

sometimes arises. Twenty files, three inches long, are enough for any number of students, if the files are collected at the end of each class. Such files may be obtained of the hardware dealer or in the local ten-cent store at five cents each.

Glass. The glass bends which pupils make early in the year should be collected at the end of the year; the long bends may have the curved ends cut off and the remaining straight piece used to make short bends, stirring rods, or glass jets the following year.

In all cases except where heat must be used, a bottle can replace a flask which is much more expensive. The bottle is not only cheaper but in case of explosions, such as those of the hydrogen generator, the bottle is safer than the flask; the flask generally flies to pieces and broken glass is thrown about the laboratory while when a similar explosion occurs in a bottle the only effect is to blow out the stopper. For the preparation of nitrogen from chemicals and in other cases where heat is used, the flask must be substituted since the bottle will not stand heat. Care should be taken to purchase or otherwise provide bottles which will take the same size stopper which must be used in the flask.

Expensive crystallizing dishes are quite unnecessary. At the ten-cent store one may buy at thirty cents a dozen glass berry dishes about four inches in diameter; these dishes have nearly vertical sides and a smooth flat bottom and answer very well for crystallizations.

Funnels with short stems are preferable to those with longer ones since the short funnel can be stood in a bottle and put away in the locker for a filtration to run to completion, whereas a long stem funnel is too tall to stand upright in the locker.

Graduates are expensive; a series of eight inch tubes etched with a scale of cubic centimeters or provided with a strip of adhesive tape attached lengthwise of the tube, marked properly, and covered with a thin layer of paraffin or Valspar will answer. Such tubes may be prepared by the students as a class exercise.

The glass plates sold by dealers are generally much larger than is necessary. The largest gas bottles likely to be used in the laboratory can be covered by a plate $2\frac{1}{2}$ inches square. A 5×5 plate therefore would make four smaller plates if cut. Probably the cheapest way is to buy window glass from the local dealer and cut it to the size wanted; a good glass cutter can be purchased for a quarter at any hardware store. The sharp

edges of the glass should be dulled by drawing a flat file across them two or three times.

Students should be cautioned not to twist thistle tubes into rubber stoppers by holding the thistle top in the hand. The top will often break off. If the tube does not work easily into the stopper, wet the glass, and if it still goes hard, do not attempt to force it in; get another thistle tube or a stopper with larger hole. If the thistle top does break off, the stem can be used to lengthen out the stem of some other thistle tube which has been broken off, or used to make a stirring rod.

A uniform size of glass tubing should be adopted, say 6 mm., and this size always ordered. The stems of thistle tubes should be of this same diameter. Larger size stems fit too tight; smaller ones do not fit tight enough.

Ring stands. The same rule applies here as applies to burners. Twenty ringstands with two rings each, are enough for two hundred students in classes of twenty at a time. Ring stand clamps are useful but not an absolute necessity.

Splints. Suitable material of this sort can be obtained by sawing straight-grained boards from old packing boxes into eight-inch lengths and splitting off the splints with a knife. Any student can do this.

Rubber. Only two sizes of stoppers seem necessary for the usual laboratory work; a small one-hole stopper to fit the test tubes used, and a larger two-hole stopper for the generator bottle or flask. The manufacturers of rubber stoppers follow the curious practice of varying the size of hole with the size of stopper, although in the laboratory we use the same size of glass tubing in all sizes of stopper. A 5½ or 6 mm. hole in all sizes is about right.

Tripods. The ordinary evaporating dish can be heated on the large ring of the stand with asbestos gauze under it. For larger sizes of dish, this is not advisable for if the hot rim of the dish comes against the cold upright of the stand, the dish will almost certainly crack. For such cases, a tripod should be used, but one or two of these is enough for the ordinary school laboratory.

Bottles. Bottles for gas collecting may be picked up almost anywhere. Each pupil may provide his own.

Reagent bottles. Bottles containing caustic solutions often cause trouble by the corrosion of the stopper so that sometimes it cannot be removed from the bottle. Inasmuch as the usual eight ounce bottle with raised letters costs about twenty-five

cents, this is a waste that should be guarded against. Dip the end of the stopper in hot paraffin and, during the summer, see that a piece of paper is inserted into the neck of the bottle between bottle and stopper. A toothpick may be used. Or use solid rubber stoppers.

Matches. In these days of cigarettes, to furnish matches in the laboratory is sheer waste. Smokers will inevitably fill their pockets with the matches supplied. A few pilot flames about the laboratory will obviate this difficulty; or a few gas lighters may be used. Such procedure also prevents the throwing of matches into the sinks which the average student never can learn not to do.

Litmus paper. The common practice of sticking the paper into the liquid in the dish when doing neutralizations is most reprehensible. Take out a drop of the liquid with stirring rod and touch it to the paper. In this way one strip will answer for half a dozen tests.

Triangles. The stems of some TD clay pipes may be broken into suitable lengths and stove pipe wire thrust through them. Use six inch lengths and twist the ends together. The boys will be glad to make these for you.

Breakage. When bottles, graduates, etc. are laid in the drawer, they always roll when the drawer is pulled out or shoved in. This causes breakage of the more fragile articles in the drawer. Bottles and graduates should not be placed in drawers but in the bottom of the locker.

Rubber connectors. Pieces of rubber tubing of proper diameter and about two inches long may be used to connect the ends of glass tubing. It is better to make an oxygen delivery tube in two or three parts, using these connectors, than it is to make it all in one piece. Arranged in this way, the tube is flexible.

Home made chemicals. If the teacher really wants to economize, many chemicals can be made in the laboratory by the students. It is not at all a difficult task to prepare antimony chloride from stibnite; barium chloride and nitrate from witherite; strontium nitrate and chloride from strontium carbonate, lead nitrate from lead oxide; magnesium sulphate from magnesium carbonate, etc. Ask Johnny to make you some copper sulphate crystals from a penny and see what his reaction will be toward that proposition.

The above are only a few of the ways in which the teacher who is forced to practice economy may do so with satisfying results.

TEACHING THE SCIENTIFIC METHOD

Article VIII: Teaching the Scientific Method in the Biology Laboratory

By Thomas F. Morrison
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As clearly brought out by the various writers who have contributed to this series of articles on the "Scientific Method," neither the inductive method nor the deductive method by itself is sufficient in solving a scientific problem. Consciously, or unconsciously, the person who is attempting to solve a research problem generally uses a combination of the two methods, since some of his work is based on previously known laws or theories which he is attempting to substantiate or disprove. If he is entering an entirely new field untouched by previous workers, then his method is primarily inductive until such time as he has collected sufficient data to permit him to formulate some hypothesis which can be tested under varying conditions. But, as soon as he has established such an hypothesis, he changes his method from the inductive to the deductive and proceeds along lines dictated by this method. The scientist, therefore, is not limited to one particular method, but, rather uses a combination of the two as the occasion demands. In Secondary School Biology a lack of background in allied subjects serves as a serious hinderance to the application of the inductive method in the majority of problems unless we fall back on the time-consuming "Heuristic Method" of Dr. Armstrong. Furthermore, the usual laboratory experiments which are suitable for a beginning class in this subject are mainly observational in nature, and the type of question which could be asked in order to develop the scientific method among students would tend to be so petty that the students would become involved in an unnecessary amount of detail in its solution.

A commonly used experiment designed to show the part played by the Law of Probability in the segregation of characteristics among members of a given generation, is the one in which the students in a class toss pennies. From the results they obtain they are asked to determine the basis for the Mendelian ratios. This experiment, if conducted along lines other than those of merely ascertaining these ratios, can be used to point out some of the characteristics of this illusive "scientific meth-

od." As will be noted, the Laws of Probability are established by the inductive method, but once the fact has been determined, this method is discarded in favor of the deductive method which is used to test the validity of the Laws.

In actual class procedure, each member of the class is given two pennies which he tosses at least fifty times, both being flipped at the same time. After each toss the student notes whether the pennies fell as two "heads," one "head" and one "tail," or two "tails," and at the conclusion of his work he enters his results in a table which has been drawn on the board. The table is transferred to his notebook after all of the data has been collected from the entire class, and he is told to total the columns and work out the averages for each group of results. This material then furnishes the data on which he is expected to draw in answering the following questions:

1. Based on the results obtained by the class as a whole, state the Law of Probability.

(This calls for an application of the inductive method. He has a relatively large amount of data—for example, five hundred tosses, if the class has ten members—and from this should be able to formulate a statement which will account for the results.)

2. What relation do the results bear to the Mendelian ratios?

(Here the method becomes deductive since the question presupposes a familiarity with the Mendelian Laws and calls for a comparison of these ratios with the results the student has obtained in his experiment.)

3. Why may the Laws of Mendel *appear* to be broken in some cases where theoretically they should hold? Base your conclusions on the data given in the chart.

(Another example of the deductive method, for here the student, knowing two different Laws, is asked to show how apparent discrepancies in the one may be interpreted by a knowledge of the other.)

4. Do your own individual results vary widely from the average of the class as a whole? Does this variance, if present, make your results worthless? How would you interpret your results?
5. Supposing that each set of results is comparable to a group of individuals in which you were studying the inheritance

of some characteristics. Would a wide variation from the total average of any single set of results lead you to doubt the validity of the Mendelian Laws? Does this bring to mind any particular danger which might face a scientist who was working on problems connected with heredity? How would he meet problems of this nature?

6. It has been said that many people are normal, but few are average. How is this borne out by the data in the chart?

The objective of this exercise is not so much to teach the Law of Probability *per se*, but, rather, to point out to the student the fallacies of basing his conclusions on too small a "population." To arrive at the correct solution of the problem, the student is required to apply both the inductive and the deductive methods of reasoning, and if these are properly applied, they enable him to establish a working hypothesis against which he can check known facts and from which he can draw valid inferences.

EULER'S THEOREM: E + 2 = F + V

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This very interesting formula, relating the number of edges, faces, and vertices of certain polyhedrons, was known to Descartes, who flourished a century before Euler. The texts on solid geometry are almost unanimous in refraining from proving it, the reason, doubtless, being that expressed in *Slaught and Lennes: Solid Geometry* (Allyn & Bacon, 1911), to wit:

> If v is the number of vertices of a convex polyhedron, e its number of edges, and f its number of faces, then $e+2=v+f$. This is called Euler's theorem. Its proof is too difficult for an elementary text book such as this. The proofs given in the current texts are not conclusive.

Such a proof one finds under this statement of the theorem in *Beman and Smith: Solid Geometry* (Ginn & Co. 1900). The proof there given is reproduced in the supplement of *Smith: Essentials of Solid Geometry* (Ginn & Co. 1924). It appears as follows:

"Proposition 1. The Polyhedron Theorem.

234. Theorem. In a polyhedron the number of edges increased by two is equal to the number of vertices increased by the number of faces.

[The diagram shows a polyhedron with six quadrilateral faces, the vertices labeled $A, B, C, D, E, F, G,$ and H.]

Given AG, a polyhedron; e, the number of edges; v the number of vertices; and f, the number of faces.

Prove that $e+2=v+f$.

Proof. For one face, as $BCGF$, $e=v$.

Adding a second face, as $ABCD$, there is formed a surface of two faces which has one edge (BC), and two vertices (B and C), common to the two faces.

Hence for two faces, $e=v+1$.

Adding a third face $ABFE$, adjoining each of the first two, this face will have two edges (AB, BF) and three vertices (A, B, F) in common with the surface of two faces.

Hence for three faces, $e=v+2$.

Similarly, for four faces, $e=v+3$, and so on.

Hence for $(f-1)$ faces, $e=v+(f-1)-1$.

Now the addition of the next face, which is the last one, will not increase the number of edges or vertices.

Hence for f faces, $e=v+f-2$, or $e+2=v+f$.

The chief flaw in the proof is obviously the failure to take note of the connectivity of the surface. No doubt it is tacitly assumed that the convexity of the polyhedrons is sufficient, as in fact it is, although no account is taken of this element in the hypothesis of the earlier text, where the restriction to convex polyhedrons casts doubt upon the validity of the theorem when applied to non-convex polyhedrons, e.g., star polyhedrons. These observations substantiate the position taken by *Slaught and Lennes*.

A few texts, including
Stone-Millis (Sanborn)
Morgan-Breckenridge (Houghton-Mifflin, 1934)
Strader-Rhoads (Winston, 1929)
Sykes-Comstock-Austin (Rand-McNally, 1933)
Nyberg (ABC, 1929)
exhibit the relation, $e+2=v+f$, and propose that the student verify it for sundry simple cases, usually for the regular solids. In general the formula is accompanied by some such statement as the following: "The theorem is true for all convex polyhedrons. The proof is too difficult for this book."

In consequence of all this the pupil, and perhaps occasionally the teacher also, suspects that the proof must be very subtle—too subtle to be intrusted to their consideration. As a matter of fact, the theorem presents an admirable opportunity to intro-

duce the notion of *connectivity* of surfaces, a simple notion which has important applications in collegiate mathematics. With the help of the idea of connectivity one can devise a very easy, and adequate, proof of the theorem. The generalization of the theorem to surfaces of n-fold connectivity follows as an easy corollary. The ensuing paragraphs are an attempt to justify these assertions.

It is of prime importance to grasp the idea of connectiveness, or connectivity, of a surface. We say that a polyhedron [in fact, any survace whatever] is *simply connected* if it is completely divided into two pieces by any single closed intersection of the surface with a plane. Such a closed section of a polyhedron is evidently a plane polygon. The ordinary surfaces of elementary solid geometry are of this sort; for example, a cutting plane may divide a cube into two rectangular parallelopipeds, or into two triangular prisms, or into other varieties of solids. We assume that the resulting bodies have faces where the section occurred, i.e., that they are also closed polyhedrons. Simple connectivity is also defined in the following terms, the two definitions being equivalent. If a closed curve drawn upon the surface can be shrunk to a point without leaving the surface, the surface is said to be *simply connected;* for example, a spherical surface is simply connected, for any closed curve, say a circle, drawn upon it can be reduced to a point without the curve's leaving the surface of the sphere. If it is possible for single sections to fail to divide the surface into two separate pieces, while two sections always completely sever the surface, we call the surface *doubly connected*. An example of such a polyhedral surface is a cube with a square hole cut through it. It is evident that a section that joints the hole with the outer periphery of the cube does not separate the surface into two disparate parts. Such a section, however, renders the surface simply connected, since any second section will completely sever the surface. In general if it is possible to make n sections without severing the surface, while the $(n+1)$th section always effects a separation, we say that the surface is *n-tuply connected*, or to have *n-fold connectivity*. Each section which does not sever the surface, accordingly, reduces the connectivity by 1; n sections which do not sever the surface render it simply connected. A simple example of a surface of n-fold connectivity is a cube with n square holes through it.

Let us now consider Euler's theorem for ordinary *simply* connected polyhedrons of solid geometry; e.g., regular solids, pyra-

mids, star polyhedrons, etc., the usual restriction of convexity being needless. Reduce all the faces of the given polyhedron to triangles by drawing in the faces having $3+n$ bounding sides the n diagonals which do not intersect one another. Clearly this does not disturb the connectivity. The value of $f+v-e$ remains unchanged by this operation; for the insertion of one diagonal creates one new face (by dividing a former face into two new faces) and one new edge (the diagonal itself), while v remains unchanged. Hence $f+v-e$ becomes $(f+1)+v-(e+1)$, or $f+v-e$. Now consider two adjoining triangular faces, ABC and DBC. Let D move into coincidence with B, thereby causing the two faces ABC and DBC, the one vertex C and the three edges, AC, CB, and CD, to disappear simultaneously. Again $f+v-e$ remains unchanged by this process, for $(f-2)+(v-1)-(e-3)=f+v-e$. Moreover this operation merely contracts the surface, and has no effect whatever upon its connectivity. Continue the process until just four triangular faces remain; i.e., until a tetrahedron remains. For the tetrahedron $f+v-e$ is obviously $4+4-6$, or 2. Since the successive steps in the process leave $f+v-e$ unchanged, it must originally have been equal to 2, i.e., $f+v-e=2$, or $f+v=e+2$.

The generalized theorem for polyhedrons of n-fold connectivity is easily proved. We simply reduce the connectivity by appropriate sections until the simple case obtains to which the relation $f+v=e-2$ applies. Let the connectivity of the given surface be reduced by one by a section which does not pass through a vertex of the polyhedron; let the section cut k edges, producing thereby 3 k new edges (k additional edges by severing k former edges, and $2k$ edges as $2k$ edges of two new polygonal faces of k sides occasioned by the section). Likewise the cut produces $k+2$ new faces (k by severing k former faces and 2 new faces in the section itself). Moreover $2k$ new vertices are produced, namely, the vertices of the two new polygonal faces in the section. Hence the reduction of connectivity by one alters $f+v-e$ to $(f+k+2)+(v+2k)-(e+3k)$, or $f+v-e+2$; i.e., the combination $f+v-e$ is increased by 2 with each single reduction in connectivity. Accordingly the reduction from n-fold connectivity to simple connectivity effects an increase of $2(n-1)$ in the value of $v+f-e$. But when simply connected, $f+v-e$ equals 2; therefore for the original n-tuply connected surface $f+v-e+2(n-1)=2$, or $f+v=e-2(n-2)$.

TIME: MATHEMATICAL AND GEOCENTRIC*

Part I. Mathematical Time

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A. THE ANTHROPOMORPHIC NOTION OF TIME

The subject upon which I venture to write is an old one, and without fear of contradiction I could assert, is as old as Time itself. It involves the third distinct physical concept of which early man became conscious, in chronological order. The two other physical concepts, or realities, which most probably had impressed their existence on the rising human intelligence in advance of that of time, being, space and mass. Of course, in stating that the three physical realities of which man first became conscious are space, mass and time, we do not want to imply that these manifested themselves before certain other realities, such as, the biological triad of pain, hunger and sex.

On the other hand, despite its venerable age the concept of time has never ceased in succeeding to enchant by its elusiveness of conception and measure, to lengthy and profound discussions and experiments through the ages of human intelligent existence, innumerable philosophers and scientists. How simple and easy was the understanding of nature and of physical phenomena in the luminous and golden times of classical and pagan Greece!

For all the phenomena the ancients found a happy and pleasant if not quite plausible explanation. A sharp burst of thunder and a flash of lightning disturbed the Attican night! Zeus was frowning—A storm furrowing the blue Ionian sea was in their imagery but Poseidon with his trident in his outstretched hand lashing the sea into fury, splitting the rocks and causing horses and fountains to spring therefrom. The earth's trembling was simply the result of the quarrels that were ornamenting the monotonous conjugal life of Aphrodite and her lame husband. On Mt. Olympus there were enough gods and demi-gods who were endowed with enough power and capriciousness to unchain the natural phenomena so that there were neither unsolvable problems nor embarrassing questions unanswerable.

Indeed, knowledge in those days was widely distributed! Had

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you asked a rich Athenian bourgeois or a cobbler installed near some rock of the Acropolis, or a brilliant hetaera, "What is time," they would have answered that time is a sinewy emaciated old man standing between a formidable scythe and an hour glass presiding over the ephemeral flow of our miserable destinies. Even today we have the same picture of old Chronos.

Since these times philosophers whose brains were tormented by the unknown have proposed other notions and explanations many of which, strange to say, have neither been changed nor improved. Aristotle affirms that "Time" is a number relative to motion or flow when it is considered as representing a part that precedes and a part that follows.

B. THE ABSOLUTE NOTION OF TIME

Twenty centuries later Newton, in his Book I of "Principia" in connection with the concept of absolute time, states "I do not define time, space, place or motion as being well known to all, only I must observe that the vulgar conceive those quantities under no other notions but from the relation they bear to sensible objects. And thence arises certain prejudices for the removing of which it will be necessary to distinguish them into absolute and relative, true and apparent, mathematical and common, time. Absolute, true and mathematical time of itself and from its own nature flows equally without regard to anything external, and by another name is called duration."

The great Laplace twenty-two centuries later wrote fundamentally very little different from the Stagirite philosopher, "Time is the impression that leaves in the memory a sequence of events of whose successive existence we are sure."

A careful study of these definitions will show that there is not much difference between the time concept of Aristotle and Plato and that of Laplace and Bergson, and I would even venture to say up to a certain point it does not differ from that of Einstein. You will notice that these three definitions sound more like metaphysical aphorisms than definitions of physical quantity. After all there is no assurance whatever that there exists in nature anything with properties like those assumed in the above definition. Physics, when reduced to concepts of this character, becomes as purely an abstract science and as far removed from reality as the abstract geometries that mathematicians built on postulates.

In particular, if we examine Newton's definition of absolute

time in the light of experimental evidence, we will find nothing in nature with such properties. Now, what seems to be the greatest contribution of Einstein and what gives a superiority to his definition over his predecessors is not so much the greater or more accurate knowledge of facts in comparison to the ancients, Newton or Laplace, but a modified view of physical concept.

Hitherto, many of the concepts of physics have been defined by laws of their properties. The new attitude toward a concept is entirely different. For instance, using one of Bridgman's examples, we may ask, "What is meant by the length of an object?" We evidently know what we mean by length if we can tell what the length of any and every object is. For the physicist, nothing more is required.

To find the length of an object, we have to perform certain physical operations. The concept of length is, therefore, fixed when the operations by which length is measured are fixed; that is, using Bridgman's expression, the concept of length involves as much as and nothing more than a set of operations by which length is determined. In general, therefore, we mean by any concept, nothing more than a set of operations, or, again using Bridgman's now famous definition; the concept is synonymous with the corresponding set of operations.

Of course, we must specify that the set of operations corresponding to or defining a given concept be a unique set, or otherwise there are possibilities of ambiguity in practical applications which we cannot admit. Applying this idea of "concept" to Newton's absolute time, we may say that we do not understand the meaning of absolute time unless we can tell how to determine the absolute time or duration of any concrete event, i.e., unless we can measure absolute time. Now we merely have to examine any of the possible operations by which we measure time to see that all such operations are relative operations. Therefore, the previous statement that absolute time does not exist, must be replaced by the statement that absolute time is meaningless. In making this statement, we are not saying anything new about nature, but we are merely bringing to light implications contained in the physical operation used in measuring time.

I remember distinctly the difficulty I had years ago, when as a student, I tried for the first time to understand Newton's definition of true and absolute time. Newton wrote about it as something almost tangible. Did he not give us all its properties

so definitely that physicists and authors of books of physics did not even comment on it! I think many students like myself felt the vacuum of pre-Einsteinian definitions of absolute time—but they kept quiet. Before Einstein the concepts of duration of an event or that of simultaneity were considered as absolute, that is, entirely independent of their external factors such as, for instance, the state of rest or motion of the observer.

According to the classical conception of time, simultaneity is a property of time events alone and nothing else: either two events are simultaneous or they are not, and the observer has nothing to do with it, nor can he affect it. The whole of science, physics and mechanics as they are still taught in our colleges and in most of our universities are based entirely upon the classical conception of time and simultaneity. In a few words, time in classical science is like a river bearing phenomena as a stream bears boats, flowing on just the same whether there were phenomena or not. Space, similarly, was rather like the bank of the river, indifferent to the ships that passed. However, from the time of Newton, if not from the time of Aristotle, a number of thoughtful metaphysicists had noticed that there was something unsatisfactory if not wrong with the definition and conception of absolute time. For instance, according to Lucretius, Epicurus in his writings states, "Time has not existence of itself, but only in material objects; from which we get the idea of past, present and future. It is impossible to conceive time in itself independently of the movement of the rest of things."

This Epicurean definition is the very negation of Newton's definition of absolute time existing of itself, etc.; yet this is the definition which Einstein has later adopted in opposition to that of Newton. These metaphysical speculations would perhaps have continued for long were it not for an unexpected fact that served to bring these questions upon a new plane, and led Einstein to give a remarkable extension to the principle of *relativity of classical mechanics* which asserts the impossibility of proving an absolute movement of translation. This unexpected fact was the issue of the celebrated experiment by Michelson on the relative motion of earth and ether performed in 1887 and published in 1888.

C. AN EPOCH MAKING EXPERIMENT

It will be preposterous for me to try at this point to explain all the experimental facts that lead to the relativistic concep-

tion of time; yet, one cannot escape mentioning some outstanding facts in a paper devoted to the discussion of time. Not to speak of the Einsteinian ideas in a paper devoted to time, would be as absurd as to speak about the daylight without mentioning the sun.

It is well known that rays of light travel across empty space from star to star, or otherwise we should be unable to see the stars. From this, physicists, long ago concluded that the rays travel in a medium that is devoid of mass and inertia, that is infinitely elastic, and which offers no resistance to the movement of material bodies into which it penetrates. This medium has been named the ether. Light travels through it as waves spread over the surface of water at a speed of 186,000 miles per second, or more precisely 299,771 kilometers per second.

The earth revolves around the sun in a veritable ocean of ether, at a speed of about eighteen miles a second. Now, the question has often been asked, "Does the earth in its orbital movement around the sun, take with it the ether which is in contact with it, as a sponge thrown out of a window takes the water which it has absorbed?" Experiment, or rather experiments, for many have been tried with the same result, has shown that the question must be answered in the negative.*

This negative answer was first established by astronomical observations in 1727. There is in astronomy a well known phenomenon discovered by Bradley which is known as aberration. When we observe a star with a telescope, the image of the star is not precisely in the direct line of vision; it appears slightly displaced. This displacement proves that the medium in which light travels, that is, the ether which fills the instrument and surrounds the earth, does not share the earth's motion. Many other experiments have settled beyond question that the ether, which is the vehicle of light, is not carried along by the earth as it travels.

Now, since the earth moves through the ether as a ship moves through the stationary waters of a lake, it ought to be possible to detect some evidence of this speed of the earth in relation to the ether. One of the devices that may be imagined for this purpose is the following. We know that the earth turns on its axis from west to east and travels around the sun in the same direc-

* An experiment performed at Clearing, Illinois in 1925 by Michelson-Gale-Pearson in connection with the velocity of light in an east-west path as compared with a west-east path gave results which can be interpreted as equally favorable to the theory of relativity or to the fixed ether theory, but these results preclude the possibility of ether drift.

tion. Neglecting the velocity of its own rotation as comparatively small we may think of the earth as moving eastward with a velocity of eighteen miles per second. Now, let us suppose that two physicists are stationed, the one at a point A, and the other at a point B, directly east of A, and that they have the necessary equipment for sending and receiving light signals. The signal that is sent from the observer at A travels toward the observer at B on the stationary ether with a velocity of 186,000 miles per second, but the observer at B also travels toward the east with a velocity of eighteen miles per second, so that the light signal on account of the motion of the earth through the ether will take a little longer to reach the point B than it would if the earth were stationary.

Inversely, when the signal is sent from the observer at B toward the observer at A, on account of the eastward motion of the earth the signal will reach that observer in a slightly shorter time than it would have if the earth were stationary. In other terms we would expect to detect a slight variation in the time of transmission of light as it travels with the earth from west to east and against the earth from east to west. This is Michelson's famous experiment reduced to its essential elements. He, however, by the use of extremely delicate and ingenuous instruments was able to perform it in a laboratory and test for possible changes in velocity, when the light was traveling with, against, and transverse to the motion of the earth. The accuracy of the experiment was such that it could detect easily any slight differences, but no such differences were found. Contrary to all expectations, and to the profound astonishment of physicists, it was found that light travels at precisely the same speed whether the man who receives the ray of light is receding before it with the velocity of the earth or is approaching it at the same velocity. It is an undeniable consequence of this experiment that the ether shares the motion of the earth. We have seen, however, that other experiments, no less precise, have settled the fact that the ether does not share the motion of the earth.

Out of these contradictions of two irreconcilable, yet indubitable facts, Einstein's splendid synthesis, came into being. But, we must not anticipate. When the negative result of Michelson's experiment was announced, there was something like consternation among the physicists of the world. Since the ether was not borne along by the earth, as observations had established, how could it possibly behave as if it did share the earth's motion?

It was absolutely necessary to find a way out of this inexplicable contradiction, to end this paradoxical mockery, which the facts seemed to oppose, to the most rigorous results of calculation. This, the men of science succeeded in doing by the method which is generally used in such circumstances, that is, by means of supplementary hypothesis. The single hypothesis, which seemed to be capable of extricating physicists from the dilemma into which Michelson had put them, was first advanced by the distinguished Irish mathematician, Fitzgerald, then taken up and developed by the celebrated Dutch physicist H. A. Lorentz.

The argument of the Fitzgerald-Lorentz hypothesis, which explains the issue of the Michelson experiment and which was, in a sense, the spring-board for Einstein's leap, follows. It was impossible to notice any change in the velocity of light because the frame in which the mirrors were fixed contracted in the direction of the earth's motion, and the contraction was such in magnitude as to compensate exactly the lengthening of the path of the ray of light, a fact which should have been detected. Michelson's experiment was repeated with many types of apparatus with the same result, indicating that the contraction is always the same irrespective of the material used. We stated that the contraction is always such that it exactly compensates for the lengthening of the path of rays of light between the two points of apparatus; in addition the Fitzgerald hypothesis states that the contraction increases in proportion as the velocity of bodies relative to the ether becomes greater. At first, this hypothesis seemed to be very strange and arbitrary; yet there was, apparently, no other way of explaining the result of Michelson's experiment.

D. THE RELATIVISTIC NOTION OF TIME

That was the state of affairs; very advanced from the point of view of mathematical expression of phenomena, but very confused, deceptive, contradictory and troublesome from the physical viewpoint when Einstein arrived. At this point, after the above short historical and factual review, we will state Einstein's principle of the constancy of the velocity of light. This principle, the center of many intellectual storms, simply states that the velocity of light is the same in all directions and independent of the state of rest or motion of the observer. This extraordinary principle rests on an experimental basis, and is

not at all a theoretical axiom as certain commentators seem to think.

As an illustration in support of Einstein's principle we may mention that the celebrated Dutch astronomer, De Sitter, has shown that the velocity of light of stars that reaches us is always the same and is independent of the fact that we approach some of the stars with velocities of hundreds of miles per second, and that we recede from others with similar velocities.

Thus, Einstein's principle rests upon the fact that up to the present it has proved quite impossible for us, by any device or movement, to add to or lessen in the least the velocity with which a ray of light reaches us. The observer finds that the speed of the light is always exactly the same relative to himself, whether the light comes from a source which rapidly approaches or recedes from him, whether he is advancing towards it, or retreating before it. The observer can always increase or lessen, relative to himself, the speed of a bullet, the speed of a wave of sound, or the speed of any moving object, by pushing forward or moving away from the object; but when the moving object is a ray of light we can do nothing of the kind, for the velocity remains constant.

This fixed speed of about 186,000 miles a second, which we always find in the case of light, it has been pointed out, is in many respects analogous to the temperature of 273°C. below zero, which is known as "absolute zero." This also is an impassable limit. All this proves that the laws which govern optical phenomena are not the same as the classical laws of mechanical phenomena. It was for this purpose of reconciling these apparently contradictory laws that Lorentz, following Fitzgerald, gave us the strange hypothesis of contraction, which Einstein modified with his clarifying and generalizing principles.

At this point we find Einstein showing us, in luminous fashion that this Lorentz-Fitzgerald contraction seems to be perfectly natural when we abandon certain conceptions—erroneous, though classical—which ruled our habitual and traditional way of estimating lengths and intervals of time. Take any object, a measuring rod, for instance. What is it that settles for us the apparent length of the rod? It is the image made upon our retina by the two rays that come from the two ends of the rod, and which reach our eye SIMULTANEOUSLY. I put this word in capital letters since it is the key to the whole matter. If the rod is stationary before us, the case is simple; but if it is moved while

we are looking at it, the case is less simple. It is so much less simple that before the work of Einstein most of our learned men and the whole of classical science thought that the instantaneous image of a rigid body was necessarily and always identical, and independent of the velocities of the body and of the observer.

The whole of classical science argued as though the spread of light were instantaneous, and as if it had an infinite velocity, a fact which is not the case. A definition of a simultaneity mentioned by Poincare, which was long considered satisfactory, is: two events are simultaneous when they are so closely bound together that analysis cannot separate without mutilating them. Possibly a beautiful definition—but, it does not tell us how to find whether two events are simultaneous or not, or at least when they are mutilated.

Another definition of simultaneity depends on what we mean when we say that one instant is after another, or one event after another. If an instant B be distinct from an instant A, and if I, at the instant A, can produce any effect, however slight, at the instant B, then this is sufficient to imply that B is after A. If this definition be granted then it follows that if A and B be distinct instants, and if I, at the instant A, cannot produce any effects at the instant B, then B is not after A. It does not, however, follow that B is before A, unless a person, at the instant B, can produce an effect at the instant A, since before and after are converse relations.

From the above definitions we would conclude that if an instant A is neither before nor after an instant B, then A ought to be simultaneous to B. However, physicists know that on account of the finite velocity of light this definition of simultaneity is satisfactory only in the case of events taking place in localities of close proximity.

Physicists familiar with Fizeau's apparatus and experiment can easily see that the above definition is neither rigorous nor sufficient when we attempt to define simultaneity of events at great distances from each other. Let us then consider what happens in Fizeau's experiment; any instant (x) at the sending apparatus, which is between the instant A of departure of a flash of light and the instant C of its return, is neither before nor after the instant B of arrival of the flash at the distant reflector. As a matter of fact, we have no means of identifying any particular instant at the sending apparatus after the in-

stant A of departure and before the instant C of return with the instant B of arrival at the reflector. The time interval AC is neither before nor after B, nor can all of it be simultaneous with the instant B. In this case the time interval AC assumes an external character. We say that it is an instant elsewhere, and we can thus see in a general way how time relations and space relations can unite in a single relationship which is best expressed by the geometrical properties of a four-dimensional continuum.

From the above considerations it is clear that the definition of simultaneity of A and B on the basis of the definition of *before* and *after* introduces the difficulty of time elsewhere. From this difficulty, as well as from the much greater difficulties of the Lorentz-Fitzgerald contraction in Michelson's experiment, we are extricated by Einstein's luminous definition of simultaneity, which he modestly calls a convention. He states that two events A and B taking place at the points P and Q are simultaneous if they appear at the same instant when observed from the middle point, M, of the space interval PQ.

This rather simple definition of simultaneity of distant events is the keystone of Einstein's theory of the relativity of time. Beginning with this definition, remaining up to the present unimpeachable, and with the fact of the constancy of the velocity of light, Einstein affirms and proves that two events that are simultaneous for a given observer are not simultaneous for another observer who is in motion with respect to the first observer.

This relativity of simultaneity is the basis of the whole Einsteinian synthesis and is in a formal contradiction with the ideas of classical Newtonian science, which affirms that two events simultaneous for one observer are simultaneous for all observers. The mathematical proof of the above proposition is given in all the special books on Relativity, while the non-mathematical proof is given in a great number of excellent books intended for the non-technical reader. Among the latter group of books and in the English translation of Einstein's *Relativity* you will find the memorable proof of simultaneity by means of the train, the embankment, and the observer.

We must mention that this proof was the center of attack of a legion of logicians, philosophers and psychologists who felt that time and its conception belonged to them and that a physicist in that field was nothing but an intruder.

The illustrious French psychologist, Bergson, after a critical study of Einstein's proof concludes in his marvelously fluid style that intuitional simultaneity is something that escapes the experimental criticism and rejects unhesitatingly the relativity of time in favor of absolute time.

Similarly, Maritain, another distinguished French metaphysicist puts as a principle that "the relativity of real time is an absurdity" and denies absolutely the right and the possibility "which," he says, "the physicists claim with a marvellous presumption, to revise our common notions of space, time, and simultaneity the elucidation of which belongs to a superior science which surpasses entirely their competence." This superior science, Maritain tells us without idle circumlocution, is the science of metaphysics.

From the above it clearly appears that by means of definition and, *a priori*, their ideas are placed above any experimental verification and above the external world which is properly the domain of physics. We shall not go further in the discussion of these general ideas, however interesting they may be. Our object here is not to occupy ourselves with the metaphysical time, but with the time that we observe, define and measure in the tangible external universe, and which is or should be the time of physicists.

"FIGHTING GRASS" BROUGHT FROM ASIA BY GOVERNMENT SCIENTISTS

Seeds of grass that "comes down a-fightin' " when blown into the air by the desert wind are among the spoils of a two-man expedition into the dry interior of Asia which has just reported to the U. S. Department of Agriculture. The grass, if torn loose from its original rootage and blown about on the sand, strikes root again. For this reason it may prove valuable in the campaign now being waged against soil erosion.

The expedition, which consisted of H. L. Westover and C. R. Enlow, spent seven months in the field, traversing much of Russian Turkistan and Asiatic Turkey. Their collections include nearly 1800 lots of seed, mostly of grasses and other plants of possible value as erosion-checks. Some of the plants may also prove to be good for re-establishing grazed-out stock ranges in the West.

Wherever they went, the two botanists report, they were hospitably received, both by Turkish and Soviet officials and by the natives of the regions visited. The Soviet government, especially, went out of its way to provide transportation and other facilities in the most difficult and out-of-the-way places.

ON THE EQUIANGULAR SPIRAL

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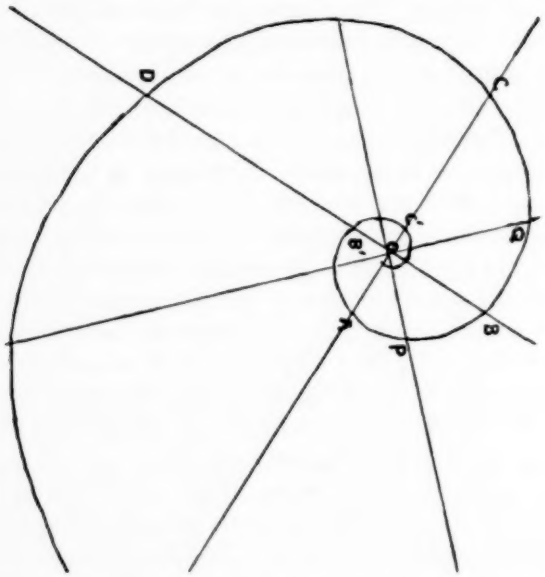
The purpose of this paper is to awaken and stimulate interest in what is today commonly called geometry by the non-specialist in mathematics, and to provoke thought regarding this subject. On account of its fundamental nature the writer thinks that the Euclidian name, elements, is more appropriate to this subject than our name, which suggests only surveying. Why was a knowledge of mathematics and music the condition imposed for becoming one of the Pythagoreans? Why did the quadrivium of liberal arts consist of arithmetic, music, geometry, and astronomy? Why have the Elements been used as a textbook for more than two thousand years? Certainly mathematics has played a very important role in education, and the writer thinks that the elements have been used more extensively in mathematics than is commonly supposed. The fact that the elements were used extensively in mathematics is evident to one who has a slight knowledge of its history. The Pythagoreans represented numbers geometrically; the Greeks and Omar Khayyam gave geometric solutions of quadratic equations; and geometrical methods were used in first solving cubic and quartic equations. The form of Newton's Principia and the extensive use in it of geometrical considerations bring to mind the importance of the elements. The writer does not intend to give a complete answer to the questions asked above; he will merely make some suggestive remarks pertaining to facts that have come to his attention. These remarks will be concerned with an aspect of the elements which has been somewhat neglected. The eighth book of Euclid is devoted chiefly to numbers in continued proportion, and the ninth book continues the discussion of geometrical progressions. The remarks made in this paper will be about the figure which represents geometrical progressions, the equiangular spiral.

The equiangular spiral, whose equation in polar coordinates is $r = ae^{b\theta}$, has the property that the values of r which correspond to values of θ forming an arithmetic progression, form a geometric progression. Therefore one may locate as many points on this curve as he wishes in the following manner. On a straight line lay off distances OA and OC, as indicated in the figure, which represent the values of r corresponding to $\theta = o$ and $\theta = \pi$

respectively. Then construct the geometric mean OB of these quantities and extend the line segment OB in both directions. Through C draw a line parallel to AB and let D be its intersection with the line OB. Through D draw a line parallel to BC and let E be its intersection with the line OA. This process may be continued. The points A, B, C, D, and E are points on the spiral. In order to extend the spiral in the opposite direction draw a line through A parallel to BC and let B' be its intersection with OB. Through B' draw a line parallel to AB and let C' be its intersection with OA. This process may be continued. The points B' and C' are points on the spiral. In order to construct other points on the curve proceed as follows. On the bisector of the angle AOB lay off the geometric mean of OA and



OB to determine the point P. On the bisector of the angle BOC lay off the geometric mean of OB and OC to determine Q. This process may be continued. The points P and Q are on the spiral. It may be noted that a circle is a special case of this curve obtained by taking OA equal to OC. In this case the common ratio in the corresponding geometric progression is unity.

First it will be pointed out how the equiangular spiral is involved in theories of computation. A table of logarithms is merely an elaborate table giving the values of θ corresponding to given values of r for points on such a spiral. For this reason

the equiangular spiral is frequently called a logarithmic spiral. In our decimal system for writing numbers the units of successive orders form terms of a geometric progression. It is only within the last several centuries that we have extended this progression backward to make use of decimal fractions. It is also interesting to note that the units of successive orders used by the ancient Egyptians form a geometric progression in which the common ratio is two. Their method for multiplying numbers will be illustrated with an example. Suppose it is desired to multiply 46 by 19. Write the numbers 19 and 46 opposite each other. Divide 19 by 2; multiply 46 by 2, and write the results under 19 and 46 respectively. Neglect the fractional part of the quotient. Continue the process as indicated in the example until the final quotient is 1. Then cross out the rows beginning with even numbers and add the numbers that remain in the right hand column to obtain the product. Clearly this method depends on the fact that 19 can be written as follows:

19	46
9	92
~~4~~	~~184~~
~~2~~	~~368~~
1	736
	874

$$19 = 1 \cdot 2^4 + 0 \cdot 2^3 + 0 \cdot 2^2 + 1 \cdot 2 + 1.$$

Geometric progressions enter also into our systems of measurement. A system like the metric system in which there is a common ratio between successive units is more convenient than one in which there is not a common ratio. It is, of course, most satisfactory to use the common ratio ten because that is the radix in our system of numeration. It is natural to use units which form a geometric progression. A few specific cases of interest will be mentioned. Astronomers have chosen their units so that there is a common ratio between the brightness of a star of one magnitude and that of a star of the next higher magnitude. The bacteriologist when he wishes to make a count of bacteria employs successive dilutions which have a common ratio to each other. By employing successive dilutions and counting the number of colonies which develop in gelatin or agar from a cubic centimeter of the most dilute solution, he can make a count, which is quite accurate, of an enormous number of organisms which are visible only when very highly magnified.

The equiangular spiral represents a law of growth. Suppose bacteria are allowed to multiply freely by cell division. Then the numbers of bacteria corresponding to time readings which form an arithmetic progression will form a geometric progression. Of

course, certain factors soon interfere with this ideal process. According to the law of Malthus the number of people in the world tends to follow an equiangular spiral. However, if a grain of wheat were allowed to reproduce itself under ideal conditions the number of grains of wheat in the world resulting from it would be an exponential function of the time. This law really applies quite generally under ideal conditions, but in every case there are natural limitations which check its operation. The equiangular spiral represents the compound interest law. Suppose a unit of money is allowed to accumulate at compound interest. Let the rate of interest per period be denoted by r. Then the amount at the end of the first interest period will be $1+r$; the amount at the end of the second interest period will be $(1+r)^2$, and the amount at the end of the nth interest period will be $(1+r)^n$. In other words, the amounts at the ends of successive interest periods will form a geometric progression whose common ratio is $1+r$. If one considers interest periods which form an arithmetic progression the corresponding amounts will form a geometric progression. The condition described here is again an ideal one; there are natural limitations which check the operation of this law. If the amount at the end of n interest periods is given one must, of course, follow the spiral in the opposite direction if he wishes to determine the present value. It follows that if one wishes to find the present value or the amount of a sequence of equal periodic payments he encounters the problem of summing a geometric series. Tables giving the compound amount of one unit and the present value of a unit are merely tables of antilogarithms to the base $1+r$ and hence tables for plotting an equiangular spiral. Since series of equal periodic payments occur so frequently in our economic life, would it be out of place to teach some of the above facts to high school students? It is seen from the discussion in this paragraph that the equiangular spiral represents a law of growth. In fact, whenever the rate of change of a quantity A is proportional to the quantity the equation which expresses A as a function of the time is the equation of the spiral $A = A_0 e^{kt}$. An author of a recent book quotes: "The American secondary school is a stronghold of conservatism whose curriculum is hopelessly traditional and not vitally connected with the needs of youth." He adds: "Everything is done to prevent life. Algebra is taught under compulsion to millions who can never use it even in intellectual play." Must not this indictment be laid at the door of the

teacher who does not understand the possibilities of his own subject? The teacher of mathematics is dealing with the very laws of growth; with fundamentals of modern business.

The equiangular spiral occurs in nature. A few cases will be mentioned. The septa of the nautilus that inspired the poet form such a spiral. Astronomers tell us that the arms of the spiral nebulae form such spirals. The galaxy, of which the sun is a part, is probably such a spiral; anyhow it is a system comparable in size to one of the spiral nebulae. Scientists have recently discovered that our galaxy is rotating. The period of rotation is about two hundred million years and the velocity of the solar system due to this rotation is about three hundred kilometers per second. Thus one can estimate the distance from the sun to the center of rotation and in this way get an idea regarding the size of the galaxy. Certainly equiangular spirals occur on a grand scale in nature.

A geometric series is fundamental in the music of the modern Occidental world. In our music the piano is standard. Now, the ratio of the frequency of one note on a piano to the frequency of the next one is the twelfth root of two. This is what we mean when we say that we use an equally tempered scale. The ratio is the twelfth root of two since there are twelve notes to the octave. The equally tempered scale has the advantage that any one of the twelve notes of the octave may serve as generating tonic for a diatonic scale.

A very interesting progression that occurs in nature is the following:

$$1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, \cdots.$$

This series has been called a summation series because the sum of any two adjacent terms equals the next term. The seeds in a sunflower head are arranged in curved rows extending from the center to the edge of the disk. If one counts the number of rows turning in a clockwise sense and the number turning in a counterclockwise sense he usually finds two adjacent terms in the above progression. The position of these terms in the progression depends upon the size of the head. In rare cases one may find multiples of terms in the progression. This series is encountered also when studying pine cones. The writer understands that it occurs quite extensively in nature but that it is perhaps most easily observed in the head of a sunflower. It will be explained in the following paragraphs that the ratio of the $(n+1)$st term

of this series to the nth term approaches a limit as n becomes infinite; in fact, the sequence of ratios converges very rapidly.

Consider any rational number. It can be written in the form x_0/x_1, where x_0 is an integer and x_1 is a positive integer. Divide x_0 by x_1. Call the quotient b_0 and the least residue x_2. If x_2 is not zero divide x_1 by x_2. Call the quotient b_1 and the remainder x_3. Continue this process until a remainder zero is obtained. The process must terminate since $x_1 > x_2 > x_3 \cdots$. Thus one obtains the set of equations

$$(1) \qquad \begin{cases} x_0 = b_0 x_1 + x_2, & (0 \leqq x_2 < x_1). \\ x_1 = b_1 x_2 + x_3, \\ \cdots \quad \cdots \\ x_{n-1} = b_{n-1} x_n + x_{n+1}, \\ x_n = b_n x_{n+1}. \end{cases}$$

If it is assumed that we did not begin with an integer, then $b_n \geqq 2$, since the x's form a decreasing sequence. The process outlined here is essentially the method given in Euclid for finding the greatest common divisor of x_0 and x_1. The number x_{n+1} is that divisor.

Now let $y_k = x_k/x_{k+1}$ $\qquad (k = 0, 1, 2, \cdots, n).$

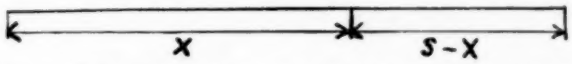
Then the equations (1) become

$$\begin{cases} y_0 = b_0 + \dfrac{1}{y_1}, \\ y_1 = b_1 + \dfrac{1}{y_2}, \\ \cdots \quad \cdots \\ y_{n-1} = b_{n-1} + \dfrac{1}{y_n}, \\ y_n = b_n. \end{cases}$$

Therefore $x_0/x_1 = y_0 = b_0 + \cfrac{1}{b_1 + \cfrac{1}{b_2 + \cfrac{1}{b_3 + \cdots + \cfrac{1}{b_n}}}}$.

Following the customary procedure, let this continued fraction be denoted by $(b_0, b_1, b_2, \cdots, b_n)$. Every rational number may be expressed in this way and conversely every expression of this form represents a rational number. The development is unique. One may wish to consider the case in which the number of b's is infinite. It has been shown in works on continued fractions that such a process always converges and that there is a one-to-one correspondence between irrational numbers and these infinite continued fractions. One may ask what is the value of the expression $(1, 1, 1, \cdots)$. Let its value be denoted by y_0. In the notation that has been introduced one has $y_0 = 1 + \frac{1}{y_1}$, where $y_1 = (1, 1, 1, \cdots) = y_0$. Therefore y_0 must be a root of the equation $x = 1 + \frac{1}{x}$. Since $y_0 > 0$ $y_0 = \frac{1+\sqrt{5}}{2}$. Next let us notice the connection between this work and the summation series. $(1) = 1$; $(1, 1) = 2/1$; $(1, 1, 1) = 3/2$; $(1, 1, 1, 1) = 5/3$; $(1, 1, 1, 1, 1) = 8/5$. Since the $(n+1)$st term in this sequence equals the ratio of the $(n+1)$st term to the nth term of the summation series, it follows from the theory of infinite continued fractions that this ratio approaches $(1+\sqrt{5})/2$ as n becomes infinite.

One may now consider a geometric progression a, ar, ar^2, ar^3, $\cdots$, which has the property that the sum of any two adjacent terms equals the next term. Then r must satisfy the equation $ar^k + ar^{k+1} = ar^{k+2}$ $(k = 0, 1, 2, \cdots)$. One is led to the equation $1 + r = r^2$, which is the same as the quadratic obtained before. Our problem is, in fact, an extension of the problem of *Golden Section* discussed in Euclid. This problem is that of dividing a line segment of length s (See figure) so that



$s/x = x/s - x$. The quantities $s - x$, x, and s are to be in geometric progression and the sum of $(s - x)$ and x is s. It follows that $x/(s-x) = (1+\sqrt{5})/2$. A rectangle in which the ratio of the length to the width is $(1+\sqrt{5})/2$ has interesting properties. It has been called the Golden Rectangle. It can be divided by a line parallel to the shorter sides into a square and a smaller

Golden Rectangle. The psychologist Fechner conducted experiments to discover the most satisfactory rectangular shape. Birkhoff in his book *Aesthetic Measure* summarizes Fechner's results as follows: "The square and more especially rectangles having dimensions approximating those of the Golden Rectangle, were generally considered to be the best."

It has recently been suggested by Jay Hambidge in his book, *The Elements of Dynamic Symmetry*, that an explanation of the methods of the Greek artists of the classical period depends upon considerations of the nature of those outlined above. However, the treatment by Hambidge is not essentially mathematical and he does not mention the connection between continued fractions and the summation series found in nature. The continued fraction $(1, 1, 1, \cdots)$ represents in a sense a complete unit. The thesis of Hambidge concerning the classical art of Greece is interesting on the one hand on account of the part played in it by geometric progressions, which are treated so extensively in Euclid, and especially on account of the use made of *Golden Section* and the equiangular spiral; and on the other hand because of its connection with laws of nature, especially a law of growth. This law is approached in nature; it is an ideal that is never attained. Many people have felt that the art of the Greeks reached a state of perfection that could only be realized by an extensive use of mathematics. Different mathematical theories of their art have been advanced, each having some merit, but the thesis of Hambidge makes a peculiar appeal to the writer. The art of the Greeks suggests life and growth; in nature we find a tendency toward the perfection which the Greek artists attained. After the mature Goethe had spent three months studying in Rome one of the questions uppermost in his mind was how did these incomparable Greek artists proceed in order to develop from the human form the forms of their gods. He says that he has a suspicion that they proceeded according to the laws followed by nature but that they have something besides which he cannot explain.

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TEACHING SCIENCE IN AN ELEMENTARY SCHOOL THAT USES THE UNIT METHOD OF INSTRUCTION*

By Helene Nichols
Manhasset Public Schools, Manhasset, New York

Elementary Science is the science of a child's surroundings. He has not grown so wise as we older folk and made divisions of it. The unit method of instruction takes a theme for the term's work in a grade. With this theme, so far as common sense dictates, all other subjects are integrated. For example, a grade is studying a particular country, the history, geography, literature and the contributions to civilization of that country are taught. The special teacher of music helps the children learn the songs of that country. Sometimes the children make up their own songs. If that country has given to the world a great composer the children are taught appreciation of his compositions. The art teacher using art as a medium of the child's expression helps the child to express himself with his art even as he does with his oral and written English. Science, too, takes its lead from the general theme. This does not mean, however, that a child's immediate interest in a discovery made that day is ignored nor does it mean that the teacher of science does not feel herself free to teach some of the material which research has found it wise that children should know. An example of this would be the teaching of material related to health.

Inasmuch as the social studies to a degree determine the theme in each grade, it may be wise here to give our program of social studies. The first grade takes up its immediate environment. The second grade gets an idea of a larger environment, its community. The third and fourth grades study man's primary needs, food, shelter and clothing. The upper fourth grade has as its theme the ancient countries of the Mediterranean and their contributions to our present civilization. The fifth grade studies the Middle Ages and the Renaissance. The upper fifth grade brings us to America through a study of the Period of Explorations. Once here the lower sixth grade makes a study of Colonial life while the upper sixth grade finishes up the work of the elementary school with the study of the Westward Movement in the United States.

* Delivered at The Department of Science Instruction of the National Education Association, July 5, 1934, Washington, D. C.

Let us take one of these themes, see how the science is brought in, what core of material is common in each grade, and how each study might lead to a hobby. Shelter is a theme for the upper third grade. In one grade the children made a large frieze on which they showed the shelter of man and animals. Here was the nest of the blackbird, the squirrel's home in a large tree, a wasp's nest and on a hill the well painted house of a man. With each of these animals the children had first hand experience. After going to see a house that was being built, John, whose father covers the stones of some buildings in New York City with a preparation to prevent weathering, brought to school a catalogue advertising his father's business. In this way we were introduced to the subject of weathering. We found that rocks that had been picked up had to be broken open before we could see the minerals of which they were made. Pieces of rusty iron, rotten wood and rotten rock were put on exhibit to show the effect of air, water and temperature on them. A glass bottle was heated and plunged into cold water. A very cold bottle was plunged into hot water. In this way we learned the effect of alternate heat and cold on the breaking up of rocks. We picked up stones as smooth as eggs which the waves of the seashore had worn down. We found these same stones were made of quartz, a material so hard that it scratched glass. On our walks we looked for roots that had penetrated and pushed apart the soil. After a rain we saw gullies worn down by running water. Our slides showed us ripples of sand in the desert and the face of the Sphinx worn partially smooth by blowing sand. We ourselves had felt the sting of grains of dust when blown by the wind into our faces. We made a chart of pictures showing how the rocks have been worn down into soil. Another chart showed dwellings made from rocks. We got into a discussion of crystals and made some. Some of us made our individual rock collections or worked together in small groups. Man's different kinds of shelter in different parts of the world were studied. We found that animal shelter in winter sometimes differs from that in summer. We found man's shelter in cold places differs from that in hot places. We emphasized the effect of seasons and climate on man's shelter, taught causes of seasons and climate insofar as the grade level permitted, and added to the class' knowledge of the causes of weather. The collecting and study of rocks was left with the children as a possible hobby. In one class we checked up among the children two years after they had had a

unit including Egypt and Greece which involved a study of rocks and found fifty per cent of them carrying on this interest.

Another teacher with her class developed the subject of shelter. Someone brought in an abandoned wasp's nest with dead members of the colony clinging to it. Frances shared with the group news of her family's bee hive. The social insects became the center of interest. How people live in communities and work together was cited. Later the children made pictures showing the natural habitat of other animals. They collected abandoned birds' nests, took walks looking for birds, visited the Roosevelt Bird Sanctuary. They made bird homes and bird baths. They listed the birds seen daily. Through watching for birds to return in the spring, they inevitably wanted to know why birds migrate. The subject of seasons and climate, their causes and their effect upon animals and man, received emphasis. This time a study of birds was the possible hobby.

A third teacher had as her theme the study of shelter. The children became immediately interested in climate, seasons, the source of the earth's heat, other stars besides the sun, the solar system and constellations. They studied the stars. At night they looked for certain constellations and reported results at school the next day even though the class as a whole was unable to hold evening meetings as one of our third grades did. They heard of the new planetarium in Philadelphia. On brown paper six feet by four they painted a semi-circular midnight blue background. On this they punched holes to represent the stars in the different constellations. On the back of these holes they pasted yellow tissue paper and when the light shone through the effect was realistic. One of these was made showing the favorite constellations for each of the four seasons of the year which incidentally showed the changing positions of these constellations. The relation of the stars and sun to us was gravely discussed. Personal experience with the seasons was described. Animal shelter and man's shelter in different climates were the subjects for two "moving pictures" the class made by drawing pictures, with explanations, and pasting them end to end into a long strip which was put on rollers. A natural habitat for a real alligator was constructed. However, the interest in the earth, the sun, the solar system, the constellations was long continued and outstanding. Once again we have as the core of material, a study of the causes and effects of the seasons, the climate, and, as a hobby, a study of stars. Carlyle once said, "Why

did not someone teach me the constellations and make me at home in the starry heavens, which are always overhead, and which I don't half know to this day?"

The question might be asked if there is any sequence in our science. The sequence is becoming more and more apparent each year as the units of work develop. Let us take the subject of electricity and follow it through the grades. A first grade studying the community made a replica of the main street of our town. It wanted a traffic light. Miniature sockets, a bulb dipped in red paint, one dipped in green, wire, a couple of knife switches and dry cells were provided. The children made their own support and rigged up their traffic light. From this they learned that there must be a source of electricity, a complete circuit if one wishes electricity to work. They also learned the function of a switch. A second grade had had a trip on a ferry boat in a fog. It returned with the question, "How does the captain know how to steer in the fog?" Compasses were provided, a trip was taken over the building, compasses were compared. It was found that all pointed in the same direction, which we learned was north, until the class clustered around an iron stairway leading to the basement. Through this we get into a simple study of magnets, compasses and just a little about how magnets are used in making electricity. A third grade planned a puppet show and wished to light its stage, to have a scene in which the lightening flashed on and off. Once again we used our miniature sockets, bulbs, wire and dry cells. Another grade was making its simple houses and put in buzzers. A fifth grade studied the period of exploration, got into a study of electricity through making two friezes of how man has found his way around the earth and the power man has used in getting around the earth. Another grade studied the Middle Ages, got into a study of electricity by trying to find out why so little space in a book on the history of science was given to the subject of science in the Middle Ages while so many pages were devoted to the study of science since that time. In a chart the children made, a sharp rise was shown in recent years when electricity has entered so largely into our advancement in transportation and communication. Simple experiments using electricity were made in connection with these friezes and charts. In this way we had repeated experiences with electricity arising out of a felt need and developing with increasing difficulty according to the grade level.

The question is sometimes asked if it is difficult to interest children in science; to get these leads from the general theme for the development into a science unit which sometimes goes on parallel with and in addition to the regular theme. Just the other day I entered a fourth grade. There were so many questions that I suggested to the grade that we omit our regular lesson, copy our questions on a chart and then as we got the answer to a question to check that question. The following is an actual list of those questions, influenced of course by previous work. It is fairly easy for me to glance over these questions and detect the newcomers to our school who have not had science through the grades.

What is heat?
How do we get mercury (mercuric oxide)?
How was the sun made?
How was the earth made?
How can the sun send its heat to the earth?
How did the sun get so hot?
Is it true the sun is 11,000°F?
Who discovered it?
How did we get so far away from the sun?
Don't you think that there may be people on Mars and Venus who think there's no one living on our planet?
Why can we see the moon?
You said that we are nearer the sun in winter than in summer, why is it hotter here in summer?
Where does the sun come from?
Do we live on the inside or the outside of the earth? Gee, why doesn't the school fall off as the earth turns around?
The earth is over us—look at the clouds.
Why does the sun stay in the air?
What makes the sky blue?
Why are the clouds white?
Why does the moon change its shape?
What is gravity?
What makes the earth go round?
Why are we farther away from the sun in summer than in winter?
How do people in heaven stay up there?
Who made the rainbow?
What makes a water spout?
Why don't we get dizzy when the earth goes round?
What makes a hurricane?
What makes a tidal wave?
What makes an earthquake?
What makes wind?
What makes wind so strong so it lifts up things as in a hurricane?
How did the first baby get born without a mother?
What makes a tide?
How did the first plant get on earth?
Why did the sun keep all its heat?
Where did the sun come from?

Our general topic is the relation of science in the school with the community. No subject deals more directly with the community and few can call forth greater opportunities for coöperation with parents than elementary science. We witnessed this recently in our school flower show. To an audience of science teachers the relation of science to the community is obvious. The community is our first source of material. Science leads to a better understanding of the community while it challenges the imagination to conceive of the effect of a scientific attitude achieved in our class-rooms and applied to our community living!

I do wish to stress, however, the contribution science makes in giving a chance for acquaintance with and pursuit of a hobby which not only makes life more interesting for the child but bids fair to hold his interest when he has grown older. Ask bird lovers, collectors of rocks, stamps or what not when they first began these hobbies which relax them and enrich their leisure. Another contribution science can make is to help prevent fear by teaching cause and effect of natural phenomena. I should also like to include, even at the cost of being thought visionary, the sense of wonder I believe a study of science fosters. Many years ago I heard a speaker say, 'it is better to live in a hut and have a palace to wonder at than to live in a palace and have nothing to wonder at.' Elementary science—aside from a discussion of subject matter, concepts, principles, skills, certain attitudes—does help, if in only a small way, those agencies which make leisure time constructive, which build for greater freedom from fear, which foster a spirit of wonder. Science must preserve its own integrity but its true significance lies in its use as a tool in helping build into a community over a period of time literally a more abundant life.

An ingenious "gadget" to assist servicemen in trouble-shooting has just been designed by A. A. Ghirardi and B. M. Freed, authors of a forthcoming publication on "Modern Radio Servicing." This gadget is now on the market.

According to the symptom detected by the serviceman, the "gadget" lists according to source, 275 possible troubles in the receiver. Six general types of symptom are shown—Hum; Weak; Noisy; Inoperative (no signals); Intermittent Reception; Fading; Oscillation and Distortion. The trouble sources are classified according to whether their location is in the Power Unit; Receiver Circuits Proper; Tubes; Reproducer; Antenna Ground; "A" Battery (if used); "B" Battery (if used); and General.

The "gadget" is being sold by Radio & Technical Publishing Co., 45 Astor Place, New York, at 25¢.

ATOMS IN ACTION

No. IV. Fingerprints of the Atoms

By W. T. Skilling

Author of "Tours Through the World of Science"

A criminal takes pains to avoid leaving finger marks around the scene of his crime. The rows of papillae in the finger tips are not only characteristic of the individual to whom they belong but are permanent in form throughout life.

The ninety-two atoms which are distributed more or less abundantly in earth and sun and stars each has a characteristic way of recording its presence. Its finger prints in the spectrum are seen and interpreted by the scientist in as unmistakable a fashion as if it had signed its name and written "I am here."

The spectrum, which like its sister the rainbow, had been a phenomenon of interested observation for many years, became, in the latter half of last century, a powerful ally of chemistry and astronomy. It is to the German physicist Gustav Kirchoff that we owe the first clear and comprehensive statement of the rules by which spectra are to be interpreted.

Joseph Fraunhofer had earlier observed both bright and dark lines of the spectrum, and had mapped hundreds of lines in the spectrum of the sun, giving to the strongest of these the names A, B, C, D, E, F, G, and H. But he did not know their significance.

Kirchoff recognized that lines, both bright and dark, are caused by certain substances in the gaseous state, and that therefore if a substance is gaseous or can be made so, its spectrum will show its composition. First, of course, it becomes necessary to try all manner of substances, especially all elements, and chart the set of lines that each one gives. Then if in an unknown source of light, such as the sun, a set of lines can be found which are in the same relative position as the lines made by a known element, it is proof positive that this element exists there.

KINDS OF SPECTRA

The early experimenters found that both solids and liquids hot enough to be luminous give a continuous spectrum devoid of any lines either bright or dark crossing it. One color blends into another as in the rainbow with no break from the red at one end to the violet at the other. Such a spectrum may be beautiful

but it is not useful for it gives no clue to composition. Iron, gold, copper, and all solid or liquid substances heated equally hot would give the same spectrum.

But if the solid iron can be changed into gaseous form by being heated intensely hot it gives a spectrum of many hundreds of lines spaced along the length of the spectrum at certain relative distances from each other, some lines weak and some strong. Copper also makes many lines but the spacing is very different from that of the iron spectrum, so that one experienced in the use of the spectroscope can tell at a glance that one spectrum is that of copper and the other that of iron.

Some elements give few lines in the visible portion of the spectrum. Sodium the metallic constituent of salt, gives only two which are very noticeable, and they are so close together that it takes a spectroscope of high power to separate them enough not to have them appear as a single line.

STUDY OF THE SUN

In order to apply the science of spectroscopy to the study of bodies of unknown composition, as the sun and stars it is first necessary to chart the lines of the spectra of as many known substances as possible. The wave lengths of these lines are recorded and compared with the wave lengths of lines in the sun if that is the source of light being studied. Or, by simply placing a spectrum of iron vapor, for example, beside a spectrum of the sun it at once becomes evident that there is iron in the sun, for hundreds of lines in the solar spectrum will match as to position and perhaps as to intensity the lines of the compared spectrum.

The lines of the spectrum of the sun have been very carefully and exactly photographed and measured. Professor Rŏwland of Johns Hopkins University was first to chart the solar lines in a comprehensive manner, recording the wave length of each. His measurements were revised and extended to include a great many more lines by Dr. St. John and other astronomers of the Mt. Wilson observatory. The revised tables give the wave length for the astonishing number of 23,000 lines, and the element producing each line is given for more than half of these.

In all about 60 of the 92 elements on earth are found to be represented by from one line to about 3000 lines each in the spectrum of the sun. Many of the missing elements are the heavier ones which naturally would sink into the deeper layers of the gaseous sun where they would not affect the spectrum.

STUDY OF STARS

The stars, too, as well as the sun, when photographed through the spectrograph, leave marks on the plate which are the sure indication of certain elements that they contain. Some of the stars, those that are of about the same temperature as the sun, have spectra almost identical with the spectrum of the sun. The same elements are shown to be present in these that are in the sun. Other stars, cooler and therefore redder than the sun, give evidence of compounds as well as elements. The sun is too hot for compounds to exist, except in the dark spots. Other stars much hotter and whiter than the sun show lines of hydrogen and helium only.

There are two possibilities to account for the peculiar spectra of these white-hot stars of few lines. One, the most obvious, is that the stars are composed of these elements only. This would suggest that perhaps all stars, including the sun, may have once consisted of hydrogen, or of hydrogen and helium only, and that the other elements in them now have been built up of these two simple substances.

There is some confirmatory evidence that this theory of the hydrogen and helium stars may be true. At least scientists are now agreed that all elements are composed of the two simple building blocks of which hydrogen is made, namely, the electron and the proton. It is therefore possible that if a star should now be made up wholly of hydrogen it might in future change this hydrogen into many elements.

Far the more probable theory, however, is that the very hot stars show the presence of hydrogen and helium only for the reason that the other elements are too highly ionized by the terrific heat of the super-hot stars to give spectral lines that can reach the earth. It is well known that light of very short wave length, such as would be given by highly ionized atoms could not penetrate the earth's atmosphere. The inference from this line of reasoning is that probably all stars are of similar composition.

CHANGED LINES WITH CHANGED TEMPERATURE

Not only do the spectral lines given by such an unknown source of radiation as a star or the sun tell what atom makes a given line, but they also tell whether that atom is in its ordinary neutral condition, or whether it is electrified by being ionized. Interpreting the lines of the spectrum is a more complicated matter than it would be if an atom always gave the *same* lines.

Research laboratories are still studying the effects of varying degrees of temperature and other physical conditions upon the character of the lines of the various elements. Some elements are more easily affected than others by heat, but in general if an atom is so disturbed by high temperature or by electrical energy as to lose one or more of its electrons, that is, to become singly or doubly or trebly ionized, it gives a new set of spectral lines. About 20 percent of the lines in the solar spectrum are due to ionized atoms.

Using the electric spark for the ionization of atoms as many as six electrons have been knocked off by the combined effect of heat and voltage. An interesting thing about the new spectral lines which are brought out by successively taking one electron after another from the atom is that the lines of the ionized spectrum resemble those of the normal atom whose outer electrons equal in number the outer electrons *remaining* on the ionized atom. Thus when magnesium, which has two electrons in its outer shell loses one of them its spectrum is strikingly similar to that of unionized sodium, which has but one electron in its outer shell.

This is a very natural thing for the radiating properties of atoms and also their chemical properties seem to be dependent upon the outer shell of electrons.

LINES SLIGHTLY OUT OF PLACE

Not only do changes in temperature produce entirely *new* lines but several conditions may cause a given line to shift slightly out of its normal place. The most notable shift of this description is that due to *motion* of the light-giving body toward or from the observer, and is known as the Doppler shift. A similar Doppler effect is often observed in sound. If, for example, a train ringing its bell is approaching you rapidly the pitch of the bell will be a little higher than if the bell were stationary. As the train passes you and goes away its pitch suddenly drops. The higher pitch during approach is due to the greater number of sound waves reaching you, per second, and the lower pitch as the train recedes is due to fewer waves.

In a similar way as a star approaches the earth more light waves reach us than if the star were stationary or receding. Therefore each line made by an approaching star is set over a trifle toward the blue end of the spectrum for that is the end made by the waves of greater frequency. Lines of a receding star are shifted toward the red.

The Doppler shift of the spectral lines could not be used to measure the speed of a light carried toward us by an automobile or a locomotive. The amount of shift would be so slight as to be imperceptible in such a spectrum for it depends on the relative velocity of the moving light source as compared with velocity of light—186,000 miles a second. Many stars move ten, twenty, thirty, or even a hundred miles a second, and in their spectra the lines are shifted by an amount easily measurable. The atoms of these stars therefore record the rate of their approach or recession upon the astronomer's photographic plate when he takes their spectrum.

THE SPECTROHELIOGRAPH

One of the cleverest of all the uses of the spectrum is that whereby the sun can be photographed in the light of *one element only*. It is as if a piece of mixed cotton and woolen goods could in some way be photographed so as to show only the cotton, or only the wool. Such a picture might show the wool to be pitifully scant. Or it might show it unevenly distributed throughout the garment. A spectroheliogram of the sun shows the distribution over the sun's surface of hydrogen or calcium and though the two elements are mixed the picture shows but one.

Briefly stated the method of taking a spectroheliogram is as follows. First a spectrum of the sun is made in the usual way, that is, by letting an image of the sun fall on the slit of the instrument and, allowing the light that passes through the slit to go through a prism. Now comes the peculiar procedure that accomplishes the above results. One line only, of the spectrum, say a line made by calcium in the sun, is allowed to pass through a second slit and fall on a photographic plate. Obviously the line made on the plate will be due to calcium light only. If now the whole of the sun's image be moved over the first slit all of the sun's calcium light will come through to the plate. But to prevent it from all falling on one narrow strip of the photographic plate the plate is moved over the second slit just as fast as the sun's image is moved over the first slit. The result is, a photograph of the sun showing where the calcium is gathered into clouds, called flocculi, and where it is thinly distributed, and where it is heaped up into towering prominences.

A similar picture can be made of hydrogen distribution by letting a line of hydrogen light instead of calcium, fall through

the second slit. Hydrogen gas will, in this picture, be seen swirling around the sun spots and rising in prominences thousands of miles high.

Thus with this spectrograph of two slits not only the existence of an element is shown, but it can be traced to its every hiding place.

DETECTIVE WORK

So, like a detective, matching known finger prints with those of unknown origin, the astronomer, by matching spectra of known origin with those made by light coming from distant stars, can tell what kinds of atoms were in the stars that reached out their finger tips and ever so lightly touched his photographic plate.

Or, to change the illustration, the spectra of given atoms are like footprints in newly fallen snow. The mark of an atom is as characteristic as the mark of a shoe having a certain pattern on the sole. As a detective could tell whether the maker of the tracks was standing or walking or running or limping or even hopping on one foot, so the trained astronomer detective can not only recognize the identity of the atom which made the spectrum but he can tell whether it was in a state of agitation or perhaps of rapid flight, can tell, even, whether or not the atom may have been limping on fewer than its normal number of electrons—that is, ionized.

Tracks in the snow can be followed even among others if not too many. But a dense crowd would so trample the snow that nothing characteristic of any one individual could be seen. In like manner atoms give their characteristic spectra only when in the gaseous state, that is, when they are not crowded by other atoms as they are in a solid or liquid substance, or even in a very compact gas. If it were not for the light gases that surround the sun and the stars, as the atmosphere surrounds the earth, their composition would forever remain unknown. The body of the sun is too compact to permit its atoms separately to record their finger prints without smudging them, or to make their separate footprints in the snow, but the less dense surrounding atmosphere can do this. Fortunately even the gases of such heavy elements as iron are up in the sun's atmosphere where they can record their presence. The intense heat of the sun holds them there in gaseous form.

Perhaps the most amazing fact growing out of our ability to study the nature of atoms in remote parts of the universe

is that however far we go, even across voids of empty space to the distant island galaxies, the atoms are the same as those right about us, and behave the same. It shows a marvelous unity in matter and in laws governing matter throughout all creation.

A QUANTITATIVE EXPERIMENT FOR HIGH SCHOOL CHEMISTRY*

By Druley Parker
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A quantitative experiment for students in high school chemistry must have the following characteristics, at least:

(a) Involve a minimum of apparatus.
(b) Use only materials ordinarily found in any laboratory.
(c) Require a minimum of experimental skill.
(d) Be safe and fool proof.
(e) Lead to the desired result, invariably and quickly.

In a course in high school there is a time when the more theoretical aspects need to be concretely illustrated by means of laboratory experiments. If a student can experimentally determine the simplest possible formula of a substance the method should seem more real and concrete to him than just reading about it from a text book.

For some time we have been searching for two quantitative experiments which would have all the above characteristics. One of these experiments we wished to use for the purpose of teaching atomic weight determination and the other for finding the simplest possible formula of a compound. No simple synthesis of a binary compound has been found by us to be satisfactory in the hands of our pupils so we have been compelled to resort to an indirect method. Several manuals describe the oxidation of tin by nitric acid as a suitable experiment for finding the atomic weight of an element. It has all the above characteristics *except that there is an element of danger from the oxides of nitrogen, the vaporized nitric acid and the use of concentrated nitric acid by amateurs*. However, by taking due precautions we have found

* This is the first of a short series of suggested experiments for high school laboratory classes; another will appear next month. Frank B. Wade, Editor for Chemistry

the experiment fairly satisfactory. The method consists of taking a weighed quantity of tin foil in a weighed crucible and adding concentrated nitric acid, drop by drop, from a glass tube, to the tin. This part of the experiment is performed in the hood. After all the tin has been attacked the mass is dried by means of a burner held in the hand, then heated strongly for a few minutes in the hood, then removed to the desk and again heated strongly for fifteen minutes, cooled to room temperature and weighed. The tin oxide obtained is in the form of heavy flakes and non-volatile. Weighings are made to a milligram only, on pulp balances. The following set of data was obtained by high school students who had had practically no experience in quantitative work.

Student No.	*Gms. Tin Used*	*At. Wt. Found*
1	0.545	116.3
2	0.348	123.7
3	0.375	121.2
4	0.668	117.4
5	0.716	114.0
6	0.636	112.0
7	0.747	110.2
8	0.794	123.3
9	0.904	118.0
10	0.770	123.0
11	0.905	121.0
12	0.712	127.0
13	0.842	125.0
14	0.932	117.0
15	0.929	120.0
16	0.463	115.0
17	0.861	119.0
18	0.218	132.0
19	0.553	118.0
20	0.323	111.0
21	0.425	119.0
22	0.608	118.0
23	0.304	112.0
	Av.	118.8

Since the value obtained by the combining weight ratio may be only the "*apparent*" atomic weight another advantage of this experiment for this purpose is that the specific heat of tin may be obtained by a demonstration before the class and the "*approximate*" atomic weight determined by the law of Dulong and Petit. By comparing the two values the "*true*" atomic weight may be found.

ASTRONOMY IN ITS RELATION TO THE TEACHING OF PHYSICS

By Robert L. Price
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Increased interest of the layman in astronomical subjects has been brought about through the so-called popular books by eminent scientists as well as through more reliable news reporting and authentic magazine articles. Such interest has led to the formation of societies for astronomical study and research. These trends are indicative of a need for teaching some of the fundamentals of astronomy to prospective high school graduates if they are to fully enjoy the literature which will acquaint them with the changing conceptions of the universe.

The problem of giving the high school or college student an adequate appreciation of astronomical phenomena and of the part of astronomy in the development of science seems to fall largely in the hands of the teacher of high school or college physics. Many teachers regret their own lack of astronomical information and understanding of the concepts of the universe. Carlyle speaks for them when he asks, "Why did not some one teach me the constellations and make me at home in the starry heavens which are always overhead?" Professor Robert Aitkin, prominent Lick Observatory astronomer, once remarked how shocked he was at questions put to him by teachers college students and graduates who visited the observatory. Teachers of science he felt should not lack a familiarity with things astronomical.

Every physics teacher knows the result of the interjection of an astronomical topic into a class discussion. Interest is aroused and one question leads to another. It reminds one of the questions of Tyndall's boys who always preferred such topics and who chose subjects not in the text. Woodhull[1] listed similar questions: What is the sun? How does it keep hot? In his study he suggested that a list be prepared of the incredible things people say and do which show the need of instruction in these matters. The result of his investigations led to the conclusion that schools should give information from the whole field of science and not neglect astronomy.

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[1] Woodhull, *The Teaching of Science*, The Macmillan Company.

Although one of the first sciences to be taught in higher schools, along with natural philosophy, surveying and chemistry, astronomy has shown a decrease in high school curricula almost to the vanishing point.[2] Most colleges give an elective, cultural course covering a quarter, semester or full year, many offering such a course in alternate years. It has been pointed out that college professors in this field have made a great contribution in many well-written textbooks and the enrollment has increased.[3] Another device through which the college may assure its freshman students of an introduction to the subject is the "Gateway" or orientation course in science. Such an introduction often proves the incentive to further reading and study by the individual.

A study of the high school science curriculum for the purpose of discovering what astronomical information a pupil might gain begins with the freshman course in general science or physiography. The content of the general science course has been studied at considerable length and the work in astronomy has been found to cover from ten to forty pages, dealing in most cases with the solar system, some of the constellations, the earth as a planet and the cause of the seasons. Davis[4] lists as other topics: the moon and its phases, eclipses, cause of day and night, comets and meteors. Downing in his book *Our Physical World* amplifies the material and stirs the imagination with star legends and lore.

The high school physiography course touches on several astronomical topics: our place in the universe, the sun's apparent path as a factor in climate, time, kinds of year, seasons, the atmosphere, earth co-ordinates, tides and the rigidity of the earth. The geography course shows less over-lapping as the chief point here is the sun's energy as a factor in climate. Latitude and longitude, time and the change of date line and the subject of navigation are topics of interest in astronomy which are discussed in geography.

Chemistry, rather than dealing directly with astronomical material, becomes an adjunct, aiding in the interpretation of spectra, from which so much of the astronomical information is obtained.

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[2] Hunter, "Science Sequence in the Junior and Senior High Schools," SCHOOL SCIENCE AND MATHEMATICS, Feb., 1933, Vol. 33, p. 214.

[3] Grier, "A Preliminary Report on Progress and Encouragement of Science Instruction in American Colleges and Universities 1912–22," SCHOOL SCIENCE AND MATHEMATICS, Oct., 1926, Vol. 26, p. 763.

[4] Davis, "Analysis of the Subject Matter of General Science," SCHOOL SCIENCE AND MATHEMATICS, June 1931, Vol. 31, p. 711

High school physics offers, without question, the greatest number of opportunities for the teaching of astronomical facts. Most of the phenomena are directly related to physics and their explanations depend on physical principles. They are important because of the general interest the pupil has in them and because of his increasing ability to grasp these explanations as a junior or senior in high school. In their use as "interest-getters," physics may teach fundamental astronomical facts much as physiography reveals many geological facts.

A great deal could be said about the objectives of science teaching at the senior high school level. Several papers and texts have discussed this quite fully. The emphasis shifts from one objective to another. It is interesting to note that while our high school texts are written from the so-called practical side, that the people who teach it emphasize the attitudes and appreciations, scientific thinking and the scientific method. The kind of knowledge of first importance is found to be that which gives an insight into the nature and organization of the environment.[5] Knowledge of useful scientific appliances is not considered one of first importance. Familiarizing the student with the environment and with modern concepts of the universe appeal to teachers as worthy and necessary objectives.[6]

Knowlton[7] defines a cultural course in college physics as "one which stimulates the imagination, broadens the interests, promotes habits of clear and sound thinking and provides the basis for continuing growth in knowledge and understanding in its field." This statement includes many of the major objectives having to do with appreciations, attitudes and interests with the knowledge aspect taken for granted. The growth of knowledge and habit of inquiry are involved. The appreciation of nature, of natural law, of beauty in natural phenomena, as well as the appreciation of the work of the great scientists and research workers results from such a course.

The attitude of confidence in the results of science is another outcome of such presentation. This is an important item as we are told that whereas the layman has had the attitude of respect and credulity toward science, the rapid change in theory has made him question scientific statements.[8] It is the old story

[5] Bergen and others, "Objectives of Science Teaching," SCHOOL SCIENCE AND MATHEMATICS, May 1931, Vol. 31, p. 550.
[6] Mulder, "Some Questions Concerning the Subject Matter in the Teaching of Physics," SCHOOL SCIENCE AND MATHEMATICS, March 1932, Vol. 32, p. 272.
[7] Knowlton, "The Cultural Course in General Physics for Colleges," SCHOOL SCIENCE AND MATHEMATICS, April 1932, Vol. 32, p. 364.
[8] Sullivan, "Science and the Layman," *Atlantic Monthly*, Sept. 1934, Vol. 154, p. 330.

of a little knowledge being a dangerous thing. To bring the student to intellectual independence has been a major aim in science. If he has an understanding of the method of science and a desire to keep abreast with the changing front, he will not need to depend on others and will be enabled to continue his growth.

In his address at the opening of the new science building of Ursinus College, Professor John R. Murlin[9] described one service of science by using the expression "to strengthen the human spirit" which he drew from Descartes. Confidence that the solution of life's problems lies in the use of reason is one source of strength. He makes the point that confidence in the human mind is gained by constant contact with the great masters of science who have achieved greatly with their minds. He relates the story of Newton's triumph, which should form a part of the training of every high school and college student.

To the teacher who would add to the experience of his students, there is not only the possibility to draw from astronomical phenomena in discussing the various branches of physics but also that of directing his study of the sky. Questions raised by the student himself as well as such he finds in his reading will open the way for discussion of astronomical topics in the class. The questions have to do with: the sky, stars, planets, planetary distances, stellar distances, possibility of other planetary systems, life on the planets, satellites, the nearest stars, the brightest stars, the stars at different hours and at different seasons, star colors, number of stars visible, the sun, sunspots, the big telescopes, the proposed telescope, meteor showers, comets, nebulae.

Supplementary topics which tie up with the regular assignments can be accumulated gradually. In a unit on molecular motion, the question of the moon's lack of atmosphere was brought up. When this was disposed of, questions regarding planetary atmospheres followed. A recent article by Dr. Walter S. Adams gives the latest information on "The Planets and Their Atmospheres."

In the study of the law of gravitation, Galileo's discovery of four of Jupiter's satellites arouses interest in the satellites of the planets. A true picture of the solar system is formed for the student in a few such discussions.

Examination of high school physics texts shows that a number

[9] Murlin, "Science and Culture," *Science*, July 27, 1934, Vol. 80, p. 81.

of such astronomical phenomena are discussed, mostly in connection with the subject of light. Here, without exception, eclipses of the sun and moon are explained by means of shadow diagrams utilizing the idea of rectilinear propagation of light. Actual eclipse conditions are not discussed. Of five texts examined two mention the light of the moon and planets, one contrasting their illumination with that of the sun and the stars which are luminous bodies.

All the texts show photographs of great telescopes in connection with the study of reflecting mirrors or the diagram of the astronomical telescope. One suggests a project on building a reflecting telescope. The velocity of light is treated by all the authors, two of whom discuss Roemer's method and one of these gives a complete discussion. The light-year is used by one and the ether is mentioned in connection with radiation. The nature of light receives some attention.

Other topics receiving attention in one or two of the textbooks are: atmospheric refraction, effect on appearance of the sun and moon at rising and setting (lift and apparent flattening), twilight, twinkling of the stars, color of the sky, determination of true north and use of the sextant.

A plate of the solar spectrum and a discussion of its meaning is given by all. Doppler's principle applied to the stars is brought out by two authors and the application of spectrum analysis to study stellar atmospheres, by one. The discovery of helium is mentioned by one. The diameter of a star is given by one author and cosmic rays are mentioned by three. The text most barren of astronomical material discusses these last two subjects.

In other branches of physics than light, the astronomical material is sparse. The subject of universal gravitation is introduced without an historical development, thereby losing the best opportunity to show the scientific method. Some other topics which have some astronomical value found scattered through these texts are: Galileo's time measurements, the earth-moon system, the mountain method of weighing the earth, the pendulum and its uses, flattening of the earth at its poles due to rotation, factors affecting gravitational pull, temperature range from absolute zero to internal temperatures of the stars special topics dealing with time, the calendar and sun-dials; biographical notes with illustrations of Galileo, Newton and others.

The sun as a source of energy is emphasized by four texts, usually in connection with radiation. Here, too, one finds the detection of starlight mentioned. The conservation of energy is discussed by two.

The relationship of physics, astronomy and mathematics is the subject of but one author. This is in sharp contrast with college textbooks in physics which devote more time to astronomical topics on the whole, especially with reference to our knowledge of the sun and stars as obtained with the telescope and its accessories, notably the photo-electric cell, camera and spectroscope. The inter-relatedness of the subjects is brought out by the use of physical methods in the study of astrophysics. Knowlton has in his *Physics for College Students* developed the idea of the sun's energy, and how it might be accounted for, in such a way that the student's interest runs through the whole course. The spectrum is discussed early in the book and the student has its use as a tool from then on. By omitting some of the older material, Knowlton can introduce the new physics much of which is related to astronomy. His paper *Sources of Energy* in SCHOOL SCIENCE AND MATHEMATICS (March and May, 1929) gives some of this material.

Current Science usually includes astronomical articles which are of great interest to high school students. This is based on the experience of Editor Webb[10] that students themselves list more astronomical questions than any others. Since many of the suggestions deal with objects in the sky at a particular time, they serve as a starting point for the student to familiarize himself with the objects about which he is studying.

What a high school pupil should be expected to know about astronomy depends largely on his experiences in general science in junior high or the high school, his training in the Scouts or some similar organization, the interest of other members of the family, and other factors which differ widely for individual cases. What he wants to know comes out of questions he asks. What he should be taught and where it should be introduced as well as how it should be presented depends largely on the particular group.

The sources of material are so numerous and varied that they must be listed separately. For the teacher who feels he knows nothing about astronomy, there are aids which will quickly put him out of that category.

[10] Webb, "The Science Young Folks Want," *Proceedings, N. E. A.*, 1928, Vol. 66.

Since astronomy finds so little place in other of the high school sciences and since the customary high school course gives so little in the way of astronomical information and problems, it is the problem of the physics teacher to introduce this supplementary material if he hopes to give the student an adequate view of the universe in which he lives. In so doing he will realize some of the worth-while objectives toward which his teaching aims, and aid his students, many of whom will have no further opportunity to be directed in just this way, not only to a better conception of the universe but to "carry his interests to the point of intellectual independence."[11]

[11] Frank, *How to Teach General Science*, P. Blakiston's Son & Co.

THE PROJECT METHOD IN BIOLOGY

By Charles G. Smith
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Purpose. The purpose of the study[1] which this paper reports was to attempt to ascertain, by means of an experimental investigation, the relative merits of the project method and the traditional method of teaching senior high school general biology, with respect to (1) knowledge of the subject matter gained by the pupils, and (2) pupil preference for the method used.

Definitions. The term project here means "an appealing concrete problem the solution of which is planned and executed by the pupil."[2] By traditional method is meant a combination of the textbook, recitation and laboratory method (teacher-demonstration and individual laboratory work).

How the problem arose. The writer has long felt that biology as usually taught falls far short of putting into practice the educational philosophy of Dewey, so generally accepted by the educational world today, namely, that the school utilize maximally the pupil's interests and activities. Even when two double laboratory periods per week are employed, the center of activity is the teacher, not the pupil, and the problems are initiated and their solution directed by the teacher. The need for a solution to this problem became all the more acute when, beginning with the term 1929–30, the school in which the writer

[1] Master's thesis: *An Experimental Study to Determine the Relative Merits of the Project and Traditional Methods of Teaching High School Biology*. U.S.C., 1931.
[2] Elliott R. Downing, *Teaching Science in the Schools*, Chicago: The University of Chicago Press, 1925, p. 103.

teaches[3] allotted for biology five periods per week, instead of seven, as heretofore. Biology, in common with other natural sciences, seems much better adapted to teaching pupils to "learn by doing," and to engage in concrete activities which seem to them worth while, than some of the non-laboratory subjects; yet, teachers of biology, the writer believes, are in a large measure failing to utilize opportunities that teachers of non-laboratory subjects might well covet.

Procedure. The rotation experimental method of McCall[4] was used in four of the writer's own classes in beginning general biology offered as an elective to tenth grade students, senior high school. (A fifth class, which used the traditional method throughout the experiment, and which was also taught by the writer, was included in the study as a check, but was not a part of the rotation experiment proper.) The classes ranged in size from 30 to 35 pupils, both sexes, and met during one forty-minute period daily. The average I.Q. was approximately 104, and the average age 15 years, 8 months.

The work was divided into two units of the same length (18 school days) and of approximately equal difficulty. During the first unit, the traditional method of teaching was applied to two of the classes, while the project method was applied to the two other classes. During the second unit, the order was reversed. The theory underlying this plan is that irrelevant factors are rotated out, so that their effects are eliminated.

Under the traditional method, two days a week were given to laboratory work and three to regular recitation work. No recitations or assignments were used in the project method. Instead, the pupils worked individually or in groups of two or three upon projects chosen from a posted list, or substituted with the teacher's permission.

A mimeographed objective test (multiple-choice, true-false, and matching) covering the work of each unit was given to both groups at the beginning of a unit and repeated at the end. The difference between the scores of these two tests constituted the pupil's improvement score. The mean improvement scores were computed for each group. The reliability of the means thus obtained was computed by McCall's experimental coefficient method.[5]

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[3] Hollywood High School, Hollywood, California.
[4] William A. McCall, *How to Experiment in Education*, New York, The Macmillan Company, 1923, Chapter VIII.
[5] McCall, *How to Experiment in Education*, pp. 154 ff.

The pupils were asked to indicate, with reasons, their preference for the method of teaching.

Statistical evaluation of the tests. The validity of the tests used in this study seems to be established by evaluating them statistically by a method suggested by Crawford,[6] who devised it as a simple yet reliable statistical procedure for evaluating tests. His plan is to give a test to two classes, one of which has studied the subject-matter covered by the test, and one of which has not. It occurred to the present writer that by the use of this method, he might attempt to evaluate the two tests of this study by using all his *IT* (initial test) scores for the class that had not studied the subject-matter, and all his *FT* (final test) scores for the class that had studied the subject-matter. These scores were, of course, all made by the same pupils (140 in all), but at different times. All the *FT*'s of a unit are thrown together, regardless of whether they are the results of the project or of the traditional method.

The procedure from here on may be briefly summarized as follows:

1. Compute the mean of the *IT* scores.
2. Compute the mean of the *FT* scores.
3. Find the difference (*D*) between these two means.
4. Compute the reliability of this *D* by using McCall's method (above referred to) for finding the Experimental Coefficient (*EC*), the formula for which is:
$$EC = \frac{D}{2.78 \times SDD}$$
5. Interpret this *D* as follows: An *EC* of 1 is taken to mean that we have "practical certainty that this test has really registered the known difference between the groups. An *EC* of 2 means that we are doubly certain, etc."

In the present study, this method yielded for the tests of the two units, *EC*'s of 3.6 and 3.4, which are high enough to justify the conclusion that the tests are of sufficient validity to measure the difference between the two groups.

Results. The sum of the mean improvement scores for both units of the four classes (111 pupils) taking part in the rotation experiment is 34.94 for the traditional method and 17.85 for the project method, with a difference of 17.09 favoring the traditional method. The standard deviation of this difference is 2.38, and the *EC*, 2.5. According to statistical tables, this difference is very reliable, and far exceeds the requirements for "practical certainty," as described by McCall.

[6] C. C. Crawford, *The Technique of Research in Education*, University of Southern California, Los Angeles, 1928, pp. 205–207.

The improvement scores under the traditional method of all four classes taking part in the rotation experiment seem fairly consistent, being 17.4, 19.5, 17.53 and 15.5 with an average of 17.48. The eighth period class, working under the traditional method during both units, has improvement scores of 15.46 and 15.77. On the other hand, the four improvement scores of the project method showed considerable variation, being 7.50, 10.26, 12.78 and 4.83, with an average of 8.84.

The pupils expressed a strong preference for the project method, on the basis of "learning more," "being more interested," "more initiative and independence," "liking to perform experiments," etc.

Conclusions. Though much experimentation is needed before a reliable evaluation can be made of the project method for teaching high school biology, the writer feels justified in drawing the following conclusions from his study.

1. Under the conditions obtaining in this experiment, better results are secured under the traditional method than under the project method if the criterion be improvement scores derived from written tests administered immediately after the completion of a month's work.
2. The results of the traditional method seem to be more uniform or consistent, the deviation from the mean being much less than in the case of the project method.
3. The pupils prefer the project method. They think they learn more under that method, though their test scores do not indicate that such is the case.
4. Some method other than the exclusive use of the project method must be found to provide pupil activity motivated by pupil interest. It may be that a wise alternation of the project method with the traditional method should be used. Or it is possible that the science laboratory, rightly used, would provide the desired environment and stimulus.
5. The guiding hand of the teacher seems to be too much withdrawn under the project method. The pupils do what at the time appeals to them, without consideration for the goals in education set up by society or the school system.
6. Many pupils seem unable to go ahead on their own initiative and solve their problems (which is a *sine qua non* of the project method) without constant reliance upon the teacher.
7. Much time seems to be lost by pupils asking for individual explanation and help, when such help could often be given to the class as a whole. But this might be considered by some as one of the values of the project method, namely that help is not given until it is needed and desired, which is the psychological time, it is claimed.
8. Personally, the writer, in view of the results of this experiment, would not, until further evidence is forthcoming, willingly employ a method of teaching based largely or exclusively on the project method as commonly defined. However, this is no indictment of pupil activity as a cardinal principle of our educational theory and practice.

Under different conditions, the results might have favored the project method. What is true for a method used only a month or two would

not necessarily hold if the experiment lasted, say a year or two. Another weakness doubtless was the fact that all the classes were taught by one teacher, who was not trained in the techniques (if such exist) of the project method.

TABLE I

SHOWING NUMBER OF PUPILS, AVE. I.Q., TIMES ABSENT, AND MEAN IMPROVEMENT SCORES FOR EACH METHOD USED IN EVERY CLASS

Class Period	*Number of Pupils*	*Ave. Chronological Age*	*Ave. I.Q.*	*Ave. Trad.*	*Times Absent Proj.*	*Mean Improvement Scores Trad.*	*Proj.*
2	30	183 mos.	106	1.30	0.5	17.40	7.50
4	25	190	100	1.24	2.32	19.50	10.26
6	29	189	103	0.73	1.62	17.53	12.78
7	27	191	108	2.63	2.40	15.50	4.83
Total	111						
Ave.	27+	188	104+	1.41	1.71	17.48	8.84
8*	29	196	98	1.41 (Unit I) 1.48 (Unit II)		15.46 (Unit I) 15.77 (Unit II)	
Gr. Total Ave. 5 classes	140 28	189.8	103	1.96		16.86	

This table should be read as follows: The class meeting during second period contained 30 pupils, with a chronological average age of 183 months, ave. IQ 106, ave. times absent 1.3 and 0.5 under traditional and project methods respectively; and mean improvement scores of 17.40 and 7.50 respectively.

* The 8th period class, not a part of the rotation experiment proper, worked under the traditional method during both units, doing the same work as the other classes when under that method. These figures are included as a check and for comparison.

TABLE II

DATA ARRANGED ACCORDING TO MCCALL'S COMPUTATION MODEL FOR THE ROTATION EXPERIMENTAL METHOD*

UNIT I

Group A Periods 4 & 6	*EF_1** Traditional Method*	*Group B Periods 2 & 7*	*EF_2 Project Method*
Number of Pupils	54	Number of Pupils	57
M_1	18.44	M_2	6.24
SD	10.81	SD	5.78
SDM_1	1.47	SDM_2	0.76

UNIT II

Group A Periods 4 & 6	*EF_2 Project Method*	*GroupB Periods 2 & 7*	*EF_1 Traditional Method*
Number of Pupils	54	Number of Pupils	57
M_3	11.61	M_4	16.50
SD	9.79	SD	8.28
SDM_3	1.33	SDM_4	1.09

SUMMARY

Traditional Method		*Project Method*	
EF_1	SDS_1	EF_2	SDS_2
$18.44+16.50$ $=34.94$	$\sqrt{1.47^2+1.09^2}$ $=1.83$	$6.24+11.61$ $=17.85$	$\sqrt{0.76^2+1.33^2}$ $=1.53$

D	*SDD*	*EC*
$34.94-17.85=17.09$	$\sqrt{1.83^2+1.53^2}=2.38$	$17.09\div(2.78\times2.38)$ $=2.5$

* McCall, *How to Experiment in Education*, p. 187. With slight alterations.
** EF_1 = Experimental Factor No. 1, here the Traditional Method of Teaching.

TABLE III

SHOWING METHOD OF DERIVING *EC*'S IN DETERMINING VALIDITY OF TESTS

	Score	*Mean*	*SD*	*SDM*	*D*	*SDD*	*EC*
Test of Unit I	*FT*	28.78	12.33	1.04			
	IT	16.39	8.04	.68			
Difference.....		12.39	.....		12.39	1.24	3.6
Test of Unit II	*FT*	56.18	13.14	1.11			
	IT	42.14	11.36	0.96			
Difference.....		14.04	.....		14.04	1.46	3.4

TABLE IV

PUPIL PREFERENCE FOR METHOD OF TEACHING USED

Method Preferred	*Number of Pupils Answering*	*Percent of Pupils Answering*
Project, if used exclusively	76	70
Traditional, if used exclusively	33	30
Alternating the two methods	70	64

This table is to be read as follows: 76 pupils, constituting 70% of those answering, expressed a preference for the Project Method, if used exclusively.

THE EFFECT ON THE ACHIEVEMENT IN PHYSICS OF DRILLS ON THE MATHEMATICAL SKILLS NEEDED IN HIGH SCHOOL PHYSICS

By Ralph G. Bailey
Great Falls High School, Great Falls, Montana

A consciousness of the need for a remedial program dealing with the mathematics in physics has been expressed by several writers. Among these are Judd[1] and Lapp.[2] The National Committee of Mathematical Requirements[3] also makes a statement to this effect.

Just what mathematics are needed in physics has been analyzed and reported in several studies, the most important of which is that of Kilzer in 1928. From the results of these studies, it was possible to build a test which would check each pupil on each type of skill, and to construct a set of drills for the development of mastery in the required skills as indicated by the test.

To check the value of such a remedial program it was decided to use four physics classes of the Great Falls high school. These 120 pupils were divided into two groups of sixty pupils each. In the beginning of the school year, in September (1933), both groups were given six tests; the Columbia Research Bureau Physics Test, Form A; the Iowa Academic Physics Test (1933); the Iowa Academic Algebra Test (1932); the Kilzer-Kirby Inventory Test for the Mathematics of High School Physics; the Physics Mathematical Test;[4] and the Terman Group Intelligence Test, Form A.

The experimental group (E) was then given the individual mathematical drills, where there was need for such, as indicated by the Physics Mathematical Test. This drill was continued one hour each day for five days, before taking up the study of the regular physics course. During the year, one and one-fourth hours were taken from class time to review and drill individuals of this group on certain mathematical skills as occasion arose. As a result, the experimental group received 127.75 hours of instruction in physics plus the 6.25 hours of mathematical drill. The control group (C) received 140 hours of instruction in

[1] Judd, C. H. *Psychology of High School Subjects*, Ginn (1915), p. 303.
[2] Lapp, C. J. *Iowa Mathematical Review for College Physics*, Form B.
[3] National Committee on Mathematical Requirements, *The Reorganization of Mathematics in Secondary Education*, The Mathematical Association of America Inc. (1923).
[4] The test built especially for the experiment from the list of skills previously analyzed.

physics. Essentially the same instruction was provided both groups through the development of a series of teaching units for the entire physics course.

In May, the groups were both given the same tests as in September with one exception; the intelligence test was omitted and a test on physics problems was used. This test was built up to check, if possible, any actual gain in the ability to use mathematical skills in the solution of physics problems.

The "matched pair" technique was used to check on the improvements made on the various tests. This method tended to eliminate those scores of either group which were extremely high or low and to permit of two practically identical groups on each initial test.

The correlation of improvement of each group on each test was used in figuring the standard deviation of the mean[5] to increase the accuracy of the comparison between the two groups.

Table 1 is a summary of the relative improvements of the two groups, as indicated by the May test results, after the September test scores were matched.

TABLE 1

SUMMARY OF THE MAY TEST RESULTS

Test	*E Group mean*	*C Group mean*	*Difference of means*	*Difference divided by SD diff.*	*Chances of true diff.*
Columbia physics	40.8	41.93	1.13	.33	63 in 100
Ia. Academic physics	38.53	35.735	2.795	1.13	87 in 100
Ia. Academic algebra	25.665	24	1.665	1.02	82 in 100
Kilzer Kirby	74.55	71.35	3.2	2.54	99 in 100
Physics math.	90.125	81	9.125	3.1	100 in 100

Conclusions drawn from the experiment are as follows:

After equating the groups on mathematical ability and in achievement in physics, on the initial tests, there was a small difference in IQs in favor of the control group. This difference was sufficient to have an effect on all test results.

The drill on the mathematical skills did definitely improve the mathematical ability of the experimental group, as shown by the results of the May testing program in mathematics.

[5] For a discussion of this see Lindquist, E. F., "The Significance of a Difference Between 'Matched' Groups," pp. 197–204, *Journal of Educational Psychology*, March, 1931.

The drill on the mathematical skills improved the ability of the experimental group in the solution of typical problems in physics.

After using a part of the class time for drill on mathematical skills, the experimental group, as shown by data on matched groups, was superior in achievement in physics.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the ones submitted in the best form will be used.

LATE SOLUTIONS

1351. *Aaron Buchman, Buffalo, Charles W. Trigg.*

1340. *Roy MacKay, Albuquerque, N. Mex.*

SOLUTION OF PROBLEMS

1352. *Proposed by Harry Frye, Tullahoma, Tenn.*

The circumference of a circle is divided into ten equal divisions with division points connected by lines through the center. The points of division are numbered clockwise as follows: 1–10–3–6–7–9–4–5–8.

The sum of the numbers for any two adjacent points equals the sum of the two opposite numbers. Using the same device, number the points so that the difference of any two adjacent numbers equals the difference of the opposite numbers.

Solutions offered by Charles W. Trigg, Los Angeles; Maxwell Reade, Brooklyn; W. E. Buker, Leetsdale, Pa.; and Jack Chidley, Missoula, Mont. are as follows:

1–9–5–8–4–10–2–6–3–7
1–9–5–4–8–10–2–6–7–3
1–2–3–4–5–10–9–8–7–6
1–2–3–6–7–10–9–8–5–4
1–2–5–8–7–10–9–6–3–4
1–5–7–9–8–10–6–4–2–3

1353. *Proposed by B. Felix John, Pittsburg.*

Given $2\sin^2\theta-\sin\alpha=1$, prove $\theta=\alpha/2+\pi/4$.

Solution by the Proposer.

$$2\sin^2\theta-\sin\alpha=1$$

$$\sin^2\theta=\tfrac{1}{2}(1+\sin\alpha)$$

$$=\frac{1}{2}\left(\cos^2\frac{\alpha}{2}+2\sin\frac{\alpha}{2}\cos\frac{\alpha}{2}+\sin^2\frac{\alpha}{2}\right)$$

$$=\frac{1}{2}\left(\cos\frac{\alpha}{2}+\sin\frac{\alpha}{2}\right)^2$$

$$\therefore\ \sin\theta=\frac{\sqrt{2}}{2}\left(\cos\frac{\alpha}{2}+\sin\frac{\alpha}{2}\right)$$

$$=\sin\frac{\pi}{4}\cos\frac{\alpha}{2}+\cos\frac{\pi}{4}\sin\frac{\alpha}{2}$$

$$=\sin\left(\frac{\pi}{4}+\frac{\alpha}{2}\right)$$

$$\therefore\quad\theta=\frac{\pi}{4}+\frac{\alpha}{2}.$$

Charles W. Trigg offers the general solution

$$\theta=(2n-1)\frac{\pi}{4}+(-1)^{n-1}\cdot\frac{\alpha}{2},\ n,\text{ any integer.}$$

Solutions also were offered by Roy MacKay, Protales, N. Mex.; Dewey C. Duncan, University of California; Maxwell Reade, Brooklyn, Wayne Webb, Tonkowa, Okla.

1354. *Proposed by Norman Anning, University of Michigan.*

Prove that it is impossible to choose real angles A, B, C, so that $\cos A\cos B+\cos B\cos C+\cos C\cos A$ may be less than -1.

Solution by the proposer.

Consider $P=\cos A\cos B+\cos B\cos C+\cos C\cos A$. It is obvious that we can choose real angles A, B, and C so as to make P as great as 3. Prove that we cannot choose real angles which will make P less than -1.

Since the angles are real, $1+\cos A$, $1+\cos B\cdots$, $1-\cos A\cdots$ are never negative.

$$(1+\cos A)(1+\cos B)(1+\cos C)\geqq 0.$$

$$(1-\cos A)(1-\cos B)(1-\cos C)\geqq 0.$$

Hence $2+2p\geqq 0$, by addition.

From this it follows at once that $P\geqq -1$.

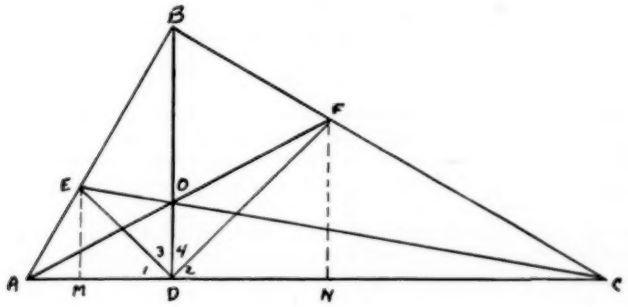
Also solved by Aaron Buchman, Buffalo, N. Y., and Dewey C. Duncan, University of California.

1355. *Proposed by William Roth, East St. Louis, Ill.*

Of three cevians of a triangle one is an altitude. Prove that the altitude bisects the angle formed by the lines drawn from the foot of the altitude to the points where the other cevians meet the sides of the triangle.

Solutions by South Philadelphia High School Math Club

FIRST SOLUTION



Given: $\triangle ABC$ with the three cevians BD, AF, EC. BD is an altitude. Lines ED and DF are drawn.

Prove: $\angle 3 = \angle 4$.

Drop $EM \perp AC$, $FN \perp AC$

$$\triangle AEM \sim \triangle ADB \therefore \frac{AM}{AD} = \frac{EM}{BD} \tag{1}$$

$$\triangle FNC \sim \triangle BDC \therefore \frac{CN}{DC} = \frac{FN}{BD} \tag{2}$$

$$\triangle ADO \sim \triangle ANF \therefore \frac{AD}{AN} = \frac{DO}{FN} \tag{3}$$

$$\triangle ODC \sim \triangle CEM \therefore \frac{CD}{CM} = \frac{DO}{EM}. \tag{4}$$

Dividing (1) by (2) $\quad \dfrac{AM \cdot DC}{AD \cdot CN} = \dfrac{EM}{FN}$

Dividing (3) by (4) $\quad \dfrac{CM \cdot AD}{CD \cdot AN} = \dfrac{EM}{FN}$

Let

$$\frac{EM}{FN} = r.$$

Then

$$\frac{AM \cdot DC}{AD \cdot CN} = r \quad \text{and} \quad \frac{CM \cdot AD}{CD \cdot AN} = r$$

$$AM \cdot DC = r(AD \cdot CN) \text{ and } CM \cdot AD = r(CD \cdot AN)$$

(5) $(AD - DM)DC = r(AD)(CD - DN)$ and (6) $(CD + DM)AD = r(CD)(AD + DN)$

From (6) $\quad CD \cdot AD + DM \cdot AD = r(AD \cdot CD + DN \cdot CD)$ (7)

and (5) $\quad CD \cdot AD - CM \cdot DM = r(AD \cdot CD - DN \cdot AD)$ (8)

Subtracting (7) − (8) $\quad DM(AD + CD) = r \cdot DN(CD + AD)$

$$r=\frac{DM}{DN}$$

$$\therefore r=\frac{DM}{DN}=\frac{EM}{FN}$$

$$\therefore \triangle EMD\sim\triangle DNF$$

$$\therefore \angle 1=\angle 2$$

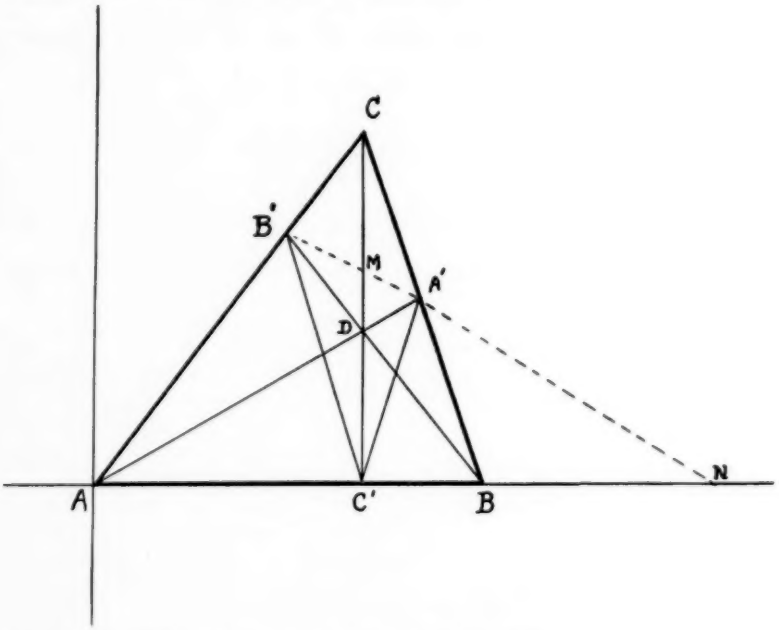
and $$\therefore \angle 3=\angle 4.$$

SECOND SOLUTION

By Dewey C. Duncan, University of California

Consider the complete quadrangle $A'C\,B'D$, which yields the four harmonic points $A\,C'B\,N$. Project from the center C these four points to $B'M\,A'N$. Hence the four rays $C'(B'M\,A'N)$ are also harmonic. But $C'M$ is perpendicular to $C\,N$. Therefore $C'B'$ and $C'A'$ make equal angles with $C'M$ (and also with the line $C'N$).

Solutions using the theorems of Ceva, Menelaus, similar triangles, law of sines and a coordinate system were offered by Charles W. Trigg, H. G. Ayre, Maxwell Reade and Dewey C. Duncan.



1356. *Proposed by Charles P. Louthan, Columbus, Ohio.*

In a right triangle, if the base is a mean proportional between the hypotenuse and altitude, express the area, the length of the base and altitude in terms of the hypotenuse.

Solved by Davis Blackwell, Centralia Township High School, Centralia, Illinois.

From the conditions of the problem, if c = hypotenuse, a = altitude and b = base, $a^2+b^2=c^2$ and $b^2=ac$ whence

$$a^2+ac-c^2=0,$$

and the altitude

$$a=\frac{(\sqrt{5}-1)}{2}c.$$

Furthermore the base

$$b=\sqrt{ac}=\left(\frac{\sqrt{5}-1}{2}\right)^{1/2}c$$

and the area

$$A=\tfrac{1}{2}ab=\frac{1}{2}\left(\frac{\sqrt{5}-1}{2}\right)^{3/2}c^2.$$

Also solved by W. E. Buker, Leetsdale, Pa., H. M. Zerbe, Wilkes-Barre, Pa., Theodosia Keeler, Sycamore, Ill., Chas. W. Trigg, Los Angeles, Calif., Dewey C. Duncan, University of California and the proposer.

1357. *Proposed by Charles W. Trigg, Los Angeles, Calif.*

Each of the first n terms of the A.P., a, $a+d$, $a+2d$, $\cdots$, is multiplied by the corresponding term of the G.P., b, br, br^2, $\cdots$, which also contains n terms. Find the sum of the first n terms of the resulting series.

Solution by the Proposer

$$S_n=ab+(a+d)br+(a+2d)br^2+\cdots+(a+[n-1]d)br^{n-1}$$
$$=ab(1+r+r^2+\cdots+r^{n-1})+bdr(1+2r+3r^2+\cdots+[n-1]r^{n-2}).$$

Now

$$\begin{aligned}1+2r+3r^2+\cdots+[n-1]r^{n-2}&=1+r+r^2+\cdots+r^{n-2}\\&\quad+r+r^2+\cdots+r^{n-2}\\&\quad+r^2+\cdots+r^{n-2}\\&\quad\cdots\cdots\cdots\\&\quad\cdots\cdots\cdots\\&\quad+r^{n-2}\\&=\frac{r^{n-1}-1}{r-1}+\frac{r^{n-1}-r}{r-1}+\frac{r^{n-1}-r^2}{r-1}+\cdots+\frac{r^{n-1}-r^{n-2}}{r-1}\\&=\frac{(n-1)r^{n-1}-(1+r+r^2+\cdots+r^{n-2})}{r-1}\\&=\frac{(r-1)(n-1)r^{n-1}-(r^{n-1}-1)}{(r-1)^2}.\end{aligned}$$

Hence,

$$S_n=b\left\{\frac{a(r^n-1)}{r-1}+\frac{dr[(r-1)(n-1)r^{n-1}-(r^{n-1}-1)]}{(r-1)^2}\right\}.$$

This may be simplified to

$$S_n=b\left\{\frac{r^n(a+dn)-a}{r-1}-\frac{dr(r^n-1)}{(r-1)^2}\right\}.$$

When $a=1$, $d=0$, this formula reduces to $\dfrac{b(r^n-1)}{r-1}$, the sum of a G.P. when $b=1$, $r=1$, S_n assumes an indeterminate form, which by differentiation with respect to r in the application of de l'Hospital's theorem reduces to $\dfrac{n}{2}[2a+(n-1)d]$, the sum of an A.P.

Also solved by Wayne Webb, Tonkawa, Okla., Dewey C. Duncan, University of California, Howard R. Harold, Tonkawa, Okla., and Aaron Buchman, Buffalo, N.Y.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below:

1352. Jack Chidlers, Missoula (Mont.) H.S.

1356. Bodner of S. Philadelphia H. S. Math. Club, William Kent, Lewis and Clark H. S., Spokane, Wash., Robert Spicher, Missoula (Mont.) H. S.

PROBLEMS FOR SOLUTION

1370. *Proposed by Hugh L. Demmer, Custer, S. D.*

(a) A cesspool pit is to be dug with the following dimensions: the top is 14 feet by 16 feet; the bottom is 10 feet square; and the depth is 8 feet. All four of the sides slope gradually from top to bottom. The work is to be paid for by the number of cubic feet of earth removed. Calculate the volume in two ways: (1) by the Prismatoid Formula; and (2) by adding the volumes of the regular solids obtained by sectioning the entire figure.

(b) Why is the following solution incorrect? The volume is equal to: average length $\times$ average width $\times$ depth, or $13 \times 12 \times 8$, or 1248 cubic feet.

(c) Why is the following solution incorrect? The volume is equal to: depth $\times$ average of top and bottom areas, or $8 \times \frac{1}{2}(224+100)$, or 1296 cubic feet.

1371. *Proposed by W. E. Buker, Leetsdale, Pa.*

Find the point the sum of whose distance from the three sides of a triangle is a minimum.

1372. *Proposed by Norman Anning, University of Michigan.*

Show that $2 \sin 18° = \sqrt{2-\sqrt{2+\sqrt{2-\sqrt{2+\cdots}}}}$ endlessly.

1373. *Proposed by W. E. Buker, Leetsdale, Pa.*

Two perpendicular lines intersect within a triangle, dividing the triangle into four parts. Determine the position of the lines so that the four parts into which the triangle is divided shall have equal areas.

1374. *Proposed by Henry Luster, Philadelphia.*

When will the hands of a stop watch that measures fifths of seconds, seconds, minutes, and hours be perpendicular to each other in this order: the second hand, the hour hand, the minute hand and the one fifth second hand. Start at 12 and let hands proceed in clockwise order.

1375. *Proposed by Allen A. Shaw.*

Given: A, B, C, D, four collinear points; prove by partial fractions Euler's Theorem $BC \cdot AD + CA \cdot BD + AB \cdot CD = 0$.

SCIENCE QUESTIONS

January, 1935
Conducted by Franklin T. Jones

Please send copies of Tests and Examinations to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

WANTED

PUZZLE QUESTIONS—NUTTY STUFF—TESTS
EXAMINATION PAPERS—ANSWERS

Answers to 669–670–671–672–673 in October, 1934. Put these questions up to classes as Miss Luz A. Santos of the Philippines did to her classes.

Questions your classes should answer correctly but do not.

Questions and Topics that aroused discussion in your classes.

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Try Mr. Wilson's Physics Tests in the November issue, and Mr. Galbreath's General Science Test in the December, 1934, issue of SCHOOL SCIENCE AND MATHEMATICS.

GUILD QUESTION RAISERS AND ANSWERERS—GQRA

Join by sending in a question or an answer. Pupils and classes are eligible. Send in your questions now. Teachers!! Let your class propose a question or send in an answer. After one year GQRA has 47 members!!

States represented—Massachusetts, Illinois, Wisconsin, Ohio, Minnesota, Connecticut, Texas, Tennessee, Pennsylvania, California, Iowa, New Jersey, New York, Maryland, Michigan, Montana, and The Philippines.

WHO STOLE THE ICE CREAM?

677. *Proposed by L. E. Hebl, Woodriver, Illinois. (Elected to GQRA, No. 80)*

Would all of Miss Peters' Boys Steal Ice Cream

Miss King learned, by some means or other, that two of the seven boys who stole the ice cream from her class picnic wore long pants. Thereupon she accused all the boys of Miss Peter's class of participating in the theft because there were just seven boys in Miss Peter's class. Miss Peters couldn't believe that all her boys would steal because none of the rascally Johnsons or Joneses were in her class (the Johnson and Jones boys were the only red-headed boys in the school). The principal, Miss Smith, settled the question quickly with the observation that all the boys over ten years old had red hair and all those under ten wore short pants, and that therefore at least some of the boys who stole Miss King's ice cream must have been from one of the other classes besides Miss Peter's. Why?

Answer by Maxwell Reade, (Elected to GQRA, No. 48) 6211–20th Avenue, Brooklyn, New York.

"Since all boys over ten are both red-headed and wear long pants—and no red-heads are in Miss Peter's class,—then we know that there are no boys above ten in Miss Peter's class. Hence the thieves, who were wearing long pants, must come from some other class."

NEW QUESTIONS

681. *Proposed by Charles C. D'Amico, Science Department, Albion High School, Albion, New York. (Elected to GQRA, No. 49.)*

Mr. Franklin T. Jones, 10109 Wilbur Ave., Cleveland, Ohio.

Dear Sir:

I have always enjoyed and derived much benefit from the Science Question Department of School Science and Mathematics. I want to commend you on the manner in which you are handling this department.

May I be so bold as to propose two problems for your department?

Problem I—A fine string passes through two small fixed rings, A and B in the same horizontal plane, and carries equal weights at its ends, hanging freely from A and B. If a third equal weight is attached to the middle point of the portion AB of the string, and is let go, prove that it will descend to a depth equal to two-thirds of the length AB below AB, and will then ascend again.

(Problem two will be published in a later number.)

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682. *Proposed through W. F. Roecker (GQRA, No. 15) Milwaukee, Wis.*

Amateur astronomers sometimes use a finder on their telescopes consisting of a tube about one inch in diameter with a pin-hole in the center of the closed end and with cross-hairs mounted on the open end. When looking at the moon through such a finder its size appears to be considerably smaller than when viewed with the naked eye. Explain.

PACKARD'S (GQRA, NO. 1) PROBLEM WORKED

627. *Proposed by J. C. Packard, Brookline, Mass.*

A rectangular block of granite (sp. gr. 2.6), 2 ft. $\times$ 3 ft. $\times$ 10 ft., lying flat on the ground upon its narrowest side, is tipped up on end. How much work is done? Note: The block must be eased down into place and not allowed to fall with a jerk. Does it make any difference at what rate this easing down into place is accomplished? Explain fully.

Solution by Charles W. Trigg, (GQRA, No. 20) Cumnock College, Los Angeles, Calif.

The density of water is 62.425 lbs./cu. ft. (at 4°C.). The mass of the granite block $= 2 \times 3 \times 10 \times 2.6 \times 62.425 = 9738.3$ lbs. Assuming this mass to be uniformly distributed, when the block is lying on the $10' \times 2'$ side (position A) its center of gravity, G, is 1.5 ft. from the ground. In tipping up the block until G and two $2'$ edges are in the same vertical plane (position B), G is raised $\sqrt{5^2 + (1.5)^2} - 1.5 = 5.22015 - 1.5 = 3.72015$ ft. The work done upon the block in lifting it to B is $3.72015 \times 9738.3 = 36{,}228$ ft. lbs.

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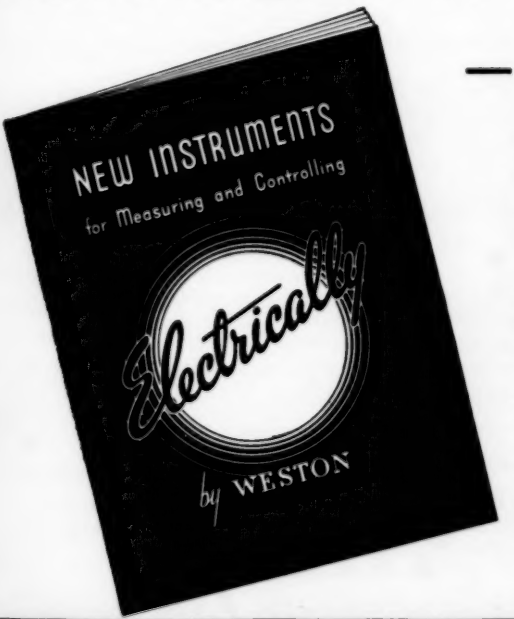

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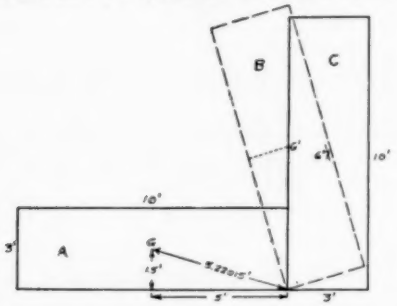
In position C, G is 5 ft. from the ground. The work done against gravity in easing the block into place is $(5.22015-5)\times 9738.3 = 2144$ ft. lbs.



When the block moves from B to C, its loss of energy is mh ft. lbs. If allowed to drop, this energy is dissipated as heat. If eased into position, so that the force of impact with the ground is negligible, this energy must be extracted by the worker. Call the distance to be lowered h, and assume that after any portion, k, of this has been traversed the block has a velocity, V. Evidently the worker has exerted an average force through this distance of $F_1 = \dfrac{mk - \dfrac{mv^2}{2g}}{k}$. During the remainder of the distance he must exert a greater force, $F_2 = \dfrac{m(h-k) + \dfrac{mv^2}{2g}}{h-k}$, in order to overcome the kinetic energy acquired, so that he may ease the block into place. The total work done $= F_1k + F_2(h-k) = mk - \dfrac{mv^2}{2g} + m(h-k) + \dfrac{mv^2}{2g} = mh$ foot pounds, regardless of the speed of lowering.

Hence, the total work done by the worker is 38,372 foot pounds, although the energy content of the block is only increased by 34,084 foot pounds, which is the useful work done on the block.

A PARADOX OF SCIENCE

668. *Proposed by Walter E. Hauswald, GQRA, #2, Beardstown High School, Beardstown, Ill.*

An iron pipe ten miles long and seven feet in diameter is placed on the earth so that it is in a perfectly straight line parallel to a tangent to the earth at the midpoint of the pipe's length.

This pipe is closed at both ends and is filled with water. When the ends are opened less than half the water will run out. Why?

Answer by Mr. Hauswald

The ends of the pipe will be higher than the middle portion of the pipe. (Higher meaning in this case distance from the center of the earth.) Therefore only a part of the water would run out the ends of the tube.

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(Put the above question and answer up to some mathematically minded student and get him to draw a figure and demonstrate to your class.

If D is center of the earth and AC the pipe 10 miles long tangent to the earth at E, and BD an earth's radius through E, then EF will be 7 ft. and the pipe will fill to points G and H along the line $HF = FG$.

$AD = BD = CD$
$BE = 7.5$ ft. (approximately)
$EF = 7$ ft.

Sketch it out and you will see that the pipe is more than half full.)

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BOOK REVIEWS

Applied Acoustics, by Harry F. Olson, Ph.D., and Frank Massa, M.Sc., of RCA Victor Research Laboratories. Cloth. 14×21 cm. Pages xiv +430. 1934. P. Blakiston's Son & Co., Inc. 1012 Walnut St., Philadelphia, Penn.

This book is intended as a text and reference manual on acoustical engineering principles. The authors have written entirely from the engineering point of view. Wherever possible complex analysis in the development of equations of electro-acoustic transducers has been avoided. A thorough understanding of the acoustic wave equation requires an elementary knowledge of partial differential equations. These derivations can, however, be omitted without losing much of the practical value of the book. The reader should be familiar with the fundamentals of physics and electric circuit theory. A complete mastery of the theory is not essential in order to obtain a practical working knowledge of the apparatus.

Theory, construction, test and operation for every type of electro-acoustic transducer are included. Laboratory tests and measurements occupy an important place. The chapters on loudspeakers and microphones will appeal to engineers and radio amateurs. Modern developments in the measurement of noise and in physiological acoustics are unique features of this book. Students and engineers of radio and architectural acoustics will find this the first American text on their problems.

C. RADIUS

The Geometry of Repeating Design and Geometry of Design for High Schools, by A. Day Bradley, Ph.D. Teachers College, Columbia University Contributions to Education, No. 549. Cloth. Pages vi+131. 1933. Bureau of Publications, Teachers College, Columbia University, New York, N.Y.

This publication is the author's dissertation offered in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Columbia University. The book is divided into two parts. Part I gives a historical survey of the subject together with illustrations and discussions of various types of repeating designs. Some of the designs are original with the author. The subject is presented from the geometrical standpoint by the use of the motions of translation, rotation, and reflection. The concept of group is introduced although no technical use is made of the term. Part II contains a number of applications for a high school course where exercises of high school level are given at appropriate places in a sequence of theorems.

For one interested in the subject, Part I furnishes an accessible summary and interpretation of much of the work that has been done in the field. Part II furnishes considerable material which could very well be used by capable high schol pupils in geometry who are interested in doing supplementary work in the course.

G. E. HAWKINS

Plane Geometry by Joseph McCormack, Head of the Department of Mathematics in Theodore Roosevelt High School, New York City, Revised Edition. Pages xiv+455, D. Appleton-Century Company, 1934. New York.

This text which is a revised edition is a decided improvement over the old edition. Many new units in space geometry have been added and the exercises have been graded and arranged for slow, average, and bright pupils. More emphasis is placed on construction work with a view to discouraging memorizing. Many new sketches, diagrams and halftones have

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Although the treatment is logical, the topics are grouped systematically to represent in each case a whole. Methods of attack and systematic thinking are emphasized throughout the book. Teachers of geometry will find the book interesting.

C. A. STONE

Junior Mathematics For Today. Book Two, by William Betz, Vice-Principal of East High School and Specialist in Mathematics for the Public Schools of Rochester, New York. Pages x+438, Ginn & Co., 1934. New York. Price $0.96

This book is designed for pupils of the second year of the Junior High School or of the eighth grade in the Elementary School. It consists of two parts, each embodying a distinctive program of work for one semester. Part one is devoted to arithmetic and geometry, while part two deals with intuitive algebra.

The book provides ample practice materials for the development and maintenance of skills, and many tests both of the diagnostic and survey type are included. A chapter on problem solving is provided for the purpose of giving the pupil some training in attacking verbal problems.

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C. A. STONE

Kegelschnittlehre, by Dr. W. Lietzmann, Oberstudiendirector of the Oberrealschule in Gottingen, Germany. Paper. Pages iv+46, 11.5×18 cm. 1933. "Mathematisch-Physikalische Bibliothek," series I, Vol. 79. B. G. Teubner, Leipzig.

Professor Lietzmann uses Conic Sections as a vehicle to show the diverse methods of attack in geometry. In six brief chapters he develops the definitions of conic sections in plane, solid, perspective, projective, and analytic geometry, and he also gives the theory of groups point of view. The idea of presenting the various aspects of conic sections in one small book seems rather unique to the reviewer. The beginner in mathematics will undoubtedly profit greatly in owning this slender volume, particularly so, if he cooperates with the author to the extent of working the indicated exercises. Thirty-four excellent drawings aid the perusal immensely. The least one can say about this volume is that it will be a fine stimulant to anyone interested in conic sections; for, it is unique in selection of material and presentation of the same.

FRED E. NICOLAI

BOOKS RECEIVED

The Calculation of the Orbits of Asteroids and Comets, by Kenneth P. Williams, Professor of Mathematics, Indiana University. Cloth. Pages vii+214. 17×25.5 cm. 1934. The Principia Press, Inc., Bloomington, Indiana.

A Textbook of Physics, by E. Grimsehl; Edited by R. Tomaschek, Professor of Physics, the University of Marburg; Authorized Translation from the Seventh German Edition by Winifred M. Deans. Volume IV, Optics.

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Volume II: The vegetation of Long Island. Part I. The vegetation of Montauk, etc. By Norman Taylor. Pub. 1923. 108 pp. Price, $1.00.

Vol. III: The vegetation of Mt. Desert Island, Maine, and its environment. By Barrington Moore and Norman Taylor. 151 pp., 27 text-figs., vegetation map in colors. June 10, 1927. Price, $1.60.

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Cloth. Pages xii+301. 14.5×22 cm. 1933. Blackie and Son, Limited, 50 Old Bailey, London, E.C. 4. Price 15s. net.

Shop Projects in Electricity, by Herbert G. Lehmann, Teacher of Shop Science, Bronxville Schools, Bronxville, N. Y. Cloth. Pages x+190. 16×22 cm. 1934. American Book Company, 330 East 22nd Street, Chicago, Ill. Price 96 cents.

Mastery Tests in General Science, by George W. Hunter, Lecturer in Methods of Education in Science, Claremont Colleges, Claremont, California, and Roy A. Knapp, Principal Antelope Valley Joint Union High School, Lancaster, California. Paper. 18×24 cm. 1934. Set X, 154 pages. Set Y, 163 pages. Price 40 cents.

Mastery Tests in Biology, by George W. Hunter, Lecturer in Methods of Education in Science, Claremont Colleges, Claremont, California, and Loran W. Ketch, Department of Biology, Herbert Hoover High School, Glendale, California. Paper. 18×24 cm. 1934. Set X, 133 pages. Set Y, 135 pages. Price 40 cents.

Objective Unit Tests on Everyday Problems in Biology, by C. J. Pieper, W. L. Beauchamp, and O. D. Frank. Form A. Paper. 48 pages. 21×27 cm. Scott, Foresman and Company, 623 South Wabash Avenue, Chicago, Ill. Price per pad 28 cents.

Objective Unit Tests on Everyday Problems in Science, by C. J. Pieper and W. L. Beauchamp. Form A. Paper. 68 pages. 21×27 cm. Scott, Foresman and Company, 623 South Wabash Avenue, Chicago, Ill. Price per pad 28 cents.

Adventures in Biology, by Julius Schwartz, Louis Eisman, Maurice Kurzman, Susan Lieberman, and Mildred Schnur, Teachers of Biology in the High Schools of the City of New York. Paper. Pages vii+59. 14×21 cm. 1934. New York Association of Biology Teachers, Grover Cleveland High School, Brooklyn, N. Y. Price 50 cents.

A History of Magic and Experimental Science, by Lynn Thorndike, Professor of History, Columbia University. Cloth. Volume III, xxvi+827 pages. Volume IV, xviii+767 pages. 13.5×22 cm. 1934. Vols. III and IV, $10.00 per set (not sold separately). Columbia University Press, 2960 Broadway, New York City.

A Scientist in the Early Republic, by Courtney Robert Hall. Cloth. Pages vi+162. 15×23 cm. 1934. Columbia University Press, 2960 Broadway, New York City. Price $2.50.

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While the color of the glass makes little difference when used in a mirror which eventually will be coated with silver, or perhaps aluminum, the great transparency of the present type glass would be significant for lens telescopes where the stellar light must pass through the glass. The largest lens, or refractor, telescope in the world today is but forty inches in diameter. It is located at the Yerkes Observatory instrument of the University of Chicago at Williams Bay, Wisconsin.—*Science Service.*